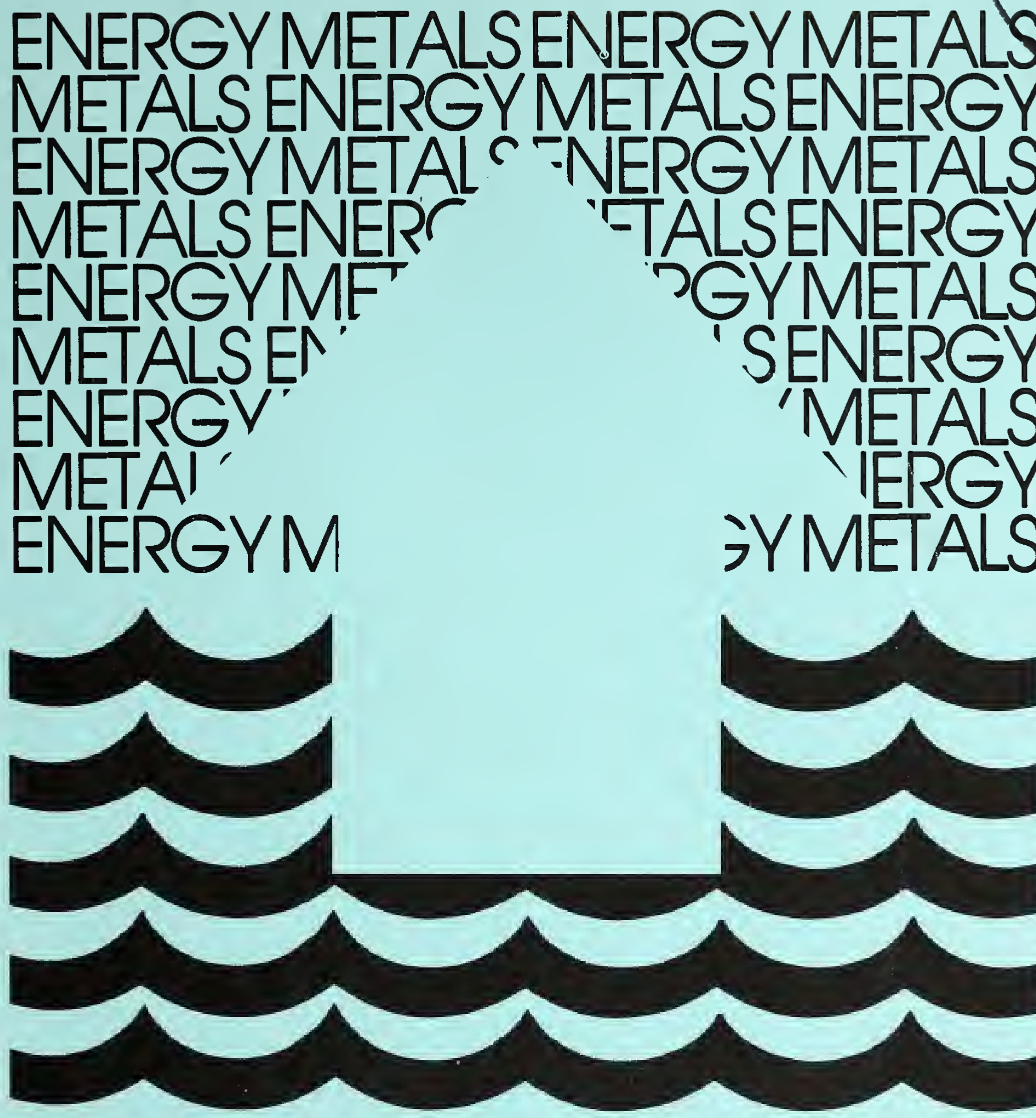

Ocean Thermal Energy Conversion

Draft Environmental Impact Statement

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office of Ocean Minerals and Energy
March 1981

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measure

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.54	centimeters	cm
ft	feet	30.	centimeters	cm
yd	yards	0.9	meters	m
fm	fathoms	1.8	meters	m
mi	statute miles	1.6	kilometers	km
nmi	nautical miles*	1.9	kilometers	km
*1 nautical mile = 6,076 feet = 1 15 statute miles				
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	squere miles	2.6	square kilometers	km^2
nmi^2	square nautical miles	3.4	square kilometers	km^2
		MASS (weight)		
oz	ounces	28.	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2.000 lb)	0.9	tonnes†	t
†1 tonne = 1,000 kg = 1 metric ton				
		VOLUME		
fl oz	fluid ounces	30.	milliliters	ml
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
gal	gallons	0.004	cubic meters	m^3
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	0.55 (°F) –32	Celsius temperature	°C
		VELOCITY		
in/sec	inches per second	2.5	centimeters per second	cm/sec
ft/sec	feet per second	30.	centimeters per second	cm/sec
ft/min	feet per minute	0.5	centimeters per second	cm/sec
mph	miles per hour	1 6	kilometers per hour	kph
kn	knots**	51	centimeters per second	cm/sec
kn	knots (nautical miles per hour)	1.9	kilometers per hour	kph
**1 knot = 1.15 mph				
		FLOW RATE		
gal/sec	gallons per second	3.8	liters per second	l/sec
gal/sec	gallons per second	0.004	cubic meters per second	m^3/sec
gal/min	gallons per minute	0.004	cubic meters per minute	m^3/min

Approximate Conversions from Metric Measure

Symbol	When You Know	Multiply by	To Find	Symbol
			LENGTH	
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
m	meters	0.6	fathoms	fm
km	kilometers	0.6	statute miles	mi
km	kilometers	0.5	nautical miles*	nmi
*1 nautical mile = 6,076 feet = 1.15 statute miles				
			AREA	
cm^2	square centimeters	0.16	square inches	in^2
m^2	squere meters	11.	square feet	ft^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
km^2	square kilometers	0.3	square nautical miles	nmi^2
			MASS (weight)	
g	grams	0.4	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes†	1 1	short tons (2.000 lb)	
†1 tonne = 1,000 kg = 1 metric ton				
			VOLUME	
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.1	quarts	qt
l	liters	0.3	gallons	gal
m^3	cubic meters	264	gallons	gal
m^3	cubic meters	35.	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
			TEMPERATURE (exact)	
°C	Celsius temperature	1.8 (°C) +32	Fahrenheit temperature	°F
			VELOCITY	
cm/sec	centimeters per second	0.4	inches per second	in/sec
cm/sec	centimeters per second	0.03	feet per second	ft/sec
cm/sec	centimetars per second	2.0	feet per minute	ft/min
cm/sec	centimeters per second	0.02	knots (nautical miles per hr)**	kn
kph	kilometers per hour	0.6	miles per hour	mph
kph	kilometers per hour	0.5	knots	kn
**1 knot = 1.15 mph				
			FLOW RATE	
l/sec	liters per second	0.3	gallons per second	gal/sec
m^3/sec	cubic meters per second	264	gallons per second	gal/sec
m^3/min	cubic meters per minute	264	gallons per second	gal/min

DRAFT
ENVIRONMENTAL IMPACT STATEMENT FOR COMMERCIAL OCEAN THERMAL ENERGY CONVERSION (OTEC) LICENSING

March 1981

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
Office of Ocean Minerals and Energy

ABSTRACT

This environmental impact statement is prepared in response to the Ocean Thermal Energy Conversion Act of 1980 (PL 96-320) and the National Environmental Policy Act of 1969, as amended, to identify and assess the effects of licensing commercial OTEC development on human activities and the atmospheric, marine, and terrestrial environments. Alternate regulatory approaches for mitigating adverse environmental impacts associated with siting, design, and operation of commercial OTEC plants are evaluated, and the preferred regulatory alternative identified.

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SUMMARY

This Environmental Impact Statement (EIS) is prepared in compliance with the National Environmental Policy Act of 1969 (NEPA), as amended, which requires an EIS for each major Federal action that significantly affects the quality of the human environment. This EIS considers the reasonably foreseeable environmental consequences inherent to commercial Ocean Thermal Energy Conversion (OTEC) development by the year 2000 under the legal regime established by the OTEC Act of 1980. Regulatory alternatives for mitigating adverse environmental impacts associated with construction, deployment, and operation of commercial OTEC plants are evaluated, and the preferred regulatory alternative is identified.

The information contained in this EIS is being used to help identify the research needs for an environmental research plan required by the OTEC Act of 1980, and to develop a technical support document that will provide guidance regarding the types of environmental information that might be submitted with an OTEC application.

Purpose of and Need for Proposed Action

In response to the demonstration of OTEC as a viable alternate energy source by the U.S. Department of Energy's OTEC program, Congress enacted two public laws to accelerate and facilitate OTEC development as a commercial energy technology. The OTEC Research, Development, and Demonstration Act (PL 96-310) calls for the acceleration of OTEC technology development to meet specific national energy goals. The OTEC Act of 1980 (PL 96-320) requires the establishment of a legal regime to permit and encourage commercial OTEC development.

The proposed action considered in this EIS is the establishment of a commercial OTEC legal regime by the Administrator of the National Oceanic and Atmospheric Administration (NOAA). The purpose of the proposed action is to promote energy self-sufficiency for the United States, protect the environment, and authorize and regulate OTEC activities subject to the jurisdiction of the OTEC Act through a one-step licensing system. The need for the legal regime is to ensure that commercial OTEC development will have due regard for the marine environment, other ocean uses, special interests of the United States, and rights and responsibilities of adjacent coastal states.

Initially, the cost of OTEC-generated electricity will be high, but will decrease as OTEC technology progresses. Because electricity in the United States' tropical-subtropical island communities is more expensive than on the mainland, OTEC-generated electricity will become cost-competitive with conventional power sources sooner in these areas. As conventional power costs continue to increase, commercialization of OTEC in the continental United States will become viable. A possible deployment scenario projects that twenty-five OTEC plants producing baseload electricity could be in operation in the Gulf of Mexico, Puerto Rico, the U.S. Virgin Islands, the Hawaiian Islands, Guam, and the Northern Mariana Islands by the year 2000, with a total output of 2100 megawatts (MWe). The energy-intensive product scenario projects that eighteen 500-MWe ammonia plantships and three 400-MWe aluminum plantships could be deployed by the year 2000.

Commercial OTEC plants utilize the temperature differential between warm surface and cold deep-ocean waters to produce electric power. Several different OTEC platform configurations and power cycle designs can be used to produce electric power from the thermal gradients in the tropical-subtropical oceans. The electricity produced could be delivered to local power grids directly (for land-based plants) or by means of submarine transmission cables. OTEC-produced electricity could also be used for the production of energy-intensive products, such as ammonia or aluminum, on plantships utilizing the thermal resources far from shore.

To utilize the ocean's thermal resource for the production of electricity, OTEC plants must draw large volumes of warm, near-surface water and cold, deep water across evaporator and condenser heat exchangers, respectively. The volume of water required for OTEC plant operation decreases as the heat exchanger efficiency and the thermal gradient increases. Assuming a conservative thermal resource gradient of $20^{\circ}C$, a 400-MWe OTEC plant would require a total volume of water equivalent to 20% of the average flow of the Mississippi River.

Alternatives to the Proposed Action

The alternative to establishing a legal regime that permits and encourages the commercial development of OTEC is the no-action alternative. Under the no-action alternative, NOAA would not issue regulations to implement the OTEC Act of 1980. The no-action alternative would result in:

- Use of existing regulations, which were not specifically prepared for the unique characteristics of OTEC, for controlling the use of the environment and preventing adverse environmental impacts.

- Discouraged development of OTEC as a commercial energy industry which could:

  - Continue the dependence of the United States on imported oil and other energy sources which pose higher environmental and economic risks than OTEC.

  - Discourage the development of industries that would construct, assemble, operate, and maintain OTEC plants.

For these reasons, the preferred alternative in this EIS is the establishment of a legal regime that permits and encourages commercial OTEC development.

The options for the siting, design, and operation of OTEC plants provide considerations for formulating regulatory alternatives within the proposed action from which the preferred legal regime can be selected. In general, OTEC operation sites must be chosen from candidate sites on the basis of siting considerations which:

- Prevent interference with other ocean-use areas, such as shipping lanes, military zones, marine sanctuaries, ocean disposal sites, commercial and recreational fisheries, ecologically-sensitive areas, and recreational areas.

- Minimize environmental disturbances.

- Minimize thermal inteference between OTEC plants.

Operation of single and multiple OTEC plants could result in adverse environmental effects. The magnitude of the potential impacts could be reduced by implementing various technological alternatives, including the utilization of various intake and discharge structure designs and biocide release methods. Alternative regulatory approaches for protecting the environment through siting and plant design include the detailed regulation approach, the moderate regulation approach, and the minimal regulation approach.

Under the detailed regulation approach, the regulations would contain detailed substantive provisions applying to all OTEC plant designs and siting environments. Specific design and siting regulations could be too rigorous, thereby unnecessarily increasing plant construction costs and reducing flexibility in siting and plant design.

The moderate regulations would contain specific guidelines and performance standards applying to all OTEC plants within a general ecosystem. This approach is commonly used to regulate mature, stable industries in which the nature of the technology and resulting environmental impacts are known. Uniform guidelines and performance standards could restrict the flexibility and experimentation required to develop OTEC as a commercial energy technology.

Under the minimal regulation alternative, minimal guidelines encompassing existing regulations would be prescribed in advance, with additional regulations developed, as required, on a case-by-case basis for inclusion as terms and conditions of a license. The minimal regulation alternative results in maximum flexibility to deal with site-specific environmental concerns, while still encouraging development of the nascent OTEC industry.

Because monitoring is required in all three alternate regulatory approaches and the minimal regulation alternative preserves the flexibility to deal effectively with site-specific environmental concerns, it is the preferred alternative. The minimal regulatory system would accomplish the goals of the OTEC Act of 1980 without interfering with technological innovations and responsible experimentation, which are part of the development of a new commercial power industry.

Affected Environment

Generically describing the atmospheric, marine, and coastal environmental conditions within the OTEC thermal resource area is critical for assessing environmental consequences of commercial OTEC development. The candidate regions likely to be used for commercial OTEC power production by the year 2000 include the eastern Gulf of Mexico, several island communities (Puerto Rico, U.S. Virgin Islands, Hawaiian Islands, Guam, and the Pacific Trust Territories), and various plantship areas located in the open ocean.

Climates within the OTEC resource area are influenced by large-scale atmospheric patterns, the sea-surface temperature of surrounding ocean waters, and the proximity of landmasses. Large-scale atmospheric disturbances (tropical cyclones) are commonly observed throughout the year in various parts of the OTEC thermal resource area, but are most frequent in the eastern and western North Pacific. Hurricanes are frequent occurrences in the Gulf of Mexico.

In general, the marine environment is composed of nearshore and offshore environments. The nearshore environment extends from the shoreline seaward to the continental shelf break and is influenced by continental conditions such as terrestrial runoff, tidal mixing, and coastal upwelling. The nearshore environment tends to be highly productive and is the location of the major world fisheries. The offshore environment is minimally influenced by continental conditions and is characterized by low productivity; however, important commercial fisheries, (i.e., tuna) do exist in the offshore environment.

The coastal environment includes the area that extends seaward and inland from the shoreline and includes the nearshore marine and terrestrial environments. The coastal environment is heavily used by man for various commercial, recreational, cultural, and military purposes, and contains many ecologically-sensitive areas which may be affected by the deployment and operation of OTEC plants.

Construction of land-based OTEC plants is most likely to occur in tropical island communities that have an adequate thermal resource close to shore. The terrestrial environments of these areas are diverse and support an extensive flora and fauna with many endemic species. The coastlines of these island communities range from minimally to extensively developed.

Environmental Consequences

Commercial OTEC development may potentially affect the atmosphere, the terrestrial environment, the marine ecosystem, and various human activities in the vicinity of deployment and operation sites. The net environmental impacts from commercial OTEC development are expected to be minimal compared to the impacts from fossil-fuel and nuclear power production; however, there are uncertainties associated with the withdrawal and redistribution of large volumes of ocean water that must be better assessed.

Potential atmospheric effects from commercial OTEC development, although less than those from equivalent fossil fuel combustion, include climatic disturbances resulting from carbon dioxide releases and sea-surface temperature cooling. Significant atmospheric effects are not expected to occur as a result of single-plant deployments; however, under extensive development scenarios, carbon dioxide releases and sea-surface cooling from multiple-plant deployments may combine synergistically to cause climatic alterations. Local air quality is not expected to be significantly affected by emissions from industrial OTEC plants producing energy-intensive products.

Construction of land-based OTEC plants may necessitate the destruction of existing terrestrial habitats and may have a local effect on noise levels, air quality, and the aesthetic quality of the construction area. These impacts will be similar to those from constructing conventional power plants.

The majority of environmental effects associated with commercial OTEC development center on the marine ecosystem, since it is the source of evaporating and condensing waters and the receiver of effluent waters used by the plant. Marine environmental effects associated with commercial OTEC development can be categorized as: (1) major (those potentially causing significant environmental impacts), (2) minor (those causing insignificant environmental disturbances), and (3) potential (those occurring only during accidents). OTEC activities that cause environmental effects corresponding to these categories include:

<u>Major Effects</u>:

- Platform presence - Biota attraction
- Withdrawal of surface and deep ocean waters - Organism entrainment and impingement
- Discharge of waters - Nutrient redistribution resulting in increased productivity
- Biocide release - Organism toxic reponse

Minor Effects:

• Protective hull-coating release	- Concentration of trace metals in organism tissues
• Power cycle erosion and corrosion	- Effect of trace constituent release
• Implantation of cold-water pipe and transmission cable	- Habitat destruction and turbidity during dredging
• Low-frequency sound production	- Interference with marine life
• Discharge of surfactants	- Organism toxic response
• Open-cycle plant operation	- Alteration of oxygen and salt concentrations in downstream waters

Potential Effects from Accidents:

• Potential working fluid release from spills and leaks	- Organism toxic response
• Potential oil releases	- Organism toxic response

Nekton populations will increase in the vicinity of the plant because of attraction to structure and lights, but will decrease in downstream areas as a result of entrainment of egg and larval stages and impingement of juvenile and adult stages. Plankton populations will be reduced immediately downstream of OTEC plants, because of entrainment and biocide release; however, the redistribution of nutrient-rich deep water into the photic zone may

stimulate plankton productivity, ultimately increasing plankton populations and fisheries. Benthic community effects will center primarily on their planktonic larval stages (meroplankton), potentially reducing recruitment stocks and adult benthic populations downstream of the plant. The cumulative effect of commercial OTEC development near island environments may significantly affect terrestrial and coastal threatened and endangered species at some sites. Commercial OTEC plant operation in oceanic regions, however, is not expected to significantly affect local threatened and endangered species.

The magnitude of potentially adverse impacts can be mitigated or reduced by implementing various siting and technology alternatives. Siting OTEC plants away from commercially-important, ecologically-sensitive, and biologically-productive areas will reduce the effects of biota attraction and avoidance, organism impingement and entrainment, and biocide release. Organism avoidance of OTEC plants can be minimized by reducing lights and noise on the platform to minimal levels required for safe plant operation. Organism impingement and entrainment may be reduced by siting intake structures at depths having the least number of organisms and by using velocity caps to achieve horizontal flow fields. Adverse environmental effects resulting from biocide release, sea-surface temperature alterations, and nutrient redistribution may be reduced by discharging the effluent waters below the photic zone. Employing alternate biocide concentrations and release schedules will minimize the effects of biocide release.

OTEC plant components will be manufactured at shipyards and industrial facilities in island communities and the continental United States. The manufacture and assembly of OTEC plants, and the modification of existing harbors and shipyard facilities, will result in the creation of construction-related jobs. The projected job impact of OTEC plant construction will be significant for large depressed city areas, where most shipyards are located. Approximately 2,000 worker-years of shipyard employment would be required to construct a 40-MWe plantship. Operation and support of OTEC plants will create additional employment opportunities.

Indirect effects of commercial OTEC development may result from the manufacture of OTEC plants, alterations in existing resource demands, and increased demands on the communities where OTEC plants are developed. Commercial OTEC development will have a positive influence on island economies by initiating a process for obtaining total energy independence, thereby creating long-term price stability for economic development. Generally, the island communities of the United States suitable for OTEC development are almost totally dependent upon imported oil, with few other viable alternatives available.

Organization of the Environmental Impact Statement

Chapter 1 specifies the purpose of and need for the proposed action, discusses legislation related to commercial OTEC development, describes OTEC technology, and presents a possible commercial OTEC deployment scenario. Chapter 2 identifies and evaluates alternatives to the proposed action, and describes the preferred regulatory approach that provides the maximum flexibility for OTEC siting and technology design, while maintaining environmental quality. Chapter 3 generically describes the atmospheric, marine, and coastal environments of the OTEC thermal resource area targeted for commercial OTEC development. Chapter 4 analyzes the environmental consequences and summarizes the cumulative environmental effects of commercial OTEC development. Chapter 5 identifies the principal and contributing authors of the EIS. Chapter 6 lists the agencies and individuals to whom the EIS was sent for review. Chapter 7 contains a glossary, a list of abbreviations, and a list of references cited.

Several appendixes are included: Appendix A contains the texts of the OTEC Act of 1980 (PL 96-320) and the OTEC Research, Development, and Demonstration Act (PL 96-310). Appendix B summarizes the status of OTEC development. Appendix C contains maps of the areas where OTEC commercialization is most probable. Appendix D presents the calculations used in impact evaluation.

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Chapter 1

PURPOSE OF AND NEED FOR THE PROPOSED ACTION

> As the supply of nonrenewable fuels is depleted and the cost of foreign oil increases, the development of OTEC as a commercial energy technology is becoming increasingly important. A legal regime is necessary to permit and encourage commercial OTEC development with due regard for protection of the marine environment and other ocean uses. The purpose of this EIS is to identify and assess the environmental effects of commercial OTEC development and evaluate regulatory alternatives that prevent, mitigate, or reduce significant impacts. This chapter discusses the status of the OTEC program, describes probable OTEC technology, and presents a possible deployment scenario to the year 2000.

1.1 INTRODUCTION

Ocean thermal energy conversion (OTEC) is a technique for the production of power using the temperature differential between warm surface and cold deep-ocean waters. The proposed action in this Environmental Impact Statement (EIS) is the establishment of a legal regime by the Administrator of the National Oceanic and Atmospheric Administration (NOAA), as directed by the OTEC Act of 1980 (PL 96-320), to permit and encourage the commercial development of OTEC. The purpose of this EIS is to evaluate the generic environmental effects of commercial OTEC development, identify significant environmental impacts, and to evaluate alternate regulatory approaches which could mitigate or reduce adverse effects. This EIS is prepared in compliance with the National Environmental Policy Act of 1969, which requires an EIS for each major Federal action that significantly affects the quality of the human environment. This EIS is programmatic in scope, considering the reasonably

foreseeable environmental consequences associated with commercial OTEC development, subject to the jurisdiction of the OTEC Act, in tropical and subtropical waters by the year 2000.

The purpose of the proposed action is to promote energy self-sufficiency for the United States, protect the environment, and authorize and regulate commercial OTEC activities conducted by United States citizens. The proposed action will provide a one-step licensing system, allowing an applicant to file a single application for an OTEC plant license which encompasses licenses and permits from all involved Federal agencies, with the exception of the U.S. Coast Guard.

The need for commercial OTEC development, as specified in the OTEC Research, Development, and Demonstration Act (PL 96-310), is evident because:

- Oil imported by the United States will continue to increase in price.
- The supply of nonrenewable fuels in the United States and throughout the world is slowly being depleted.
- OTEC is a renewable energy resource that can make a significant contribution to the United States' energy needs.

A 400 megawatt (MWe) OTEC plant could power approximately 6×10^4 households for a year, saving 2×10^6 metric tons of coal or 6×10^6 barrels of oil per year. A 500-MWe OTEC plant producing ammonia would save 6×10^8 m^3 of natural gas per year; a 400-MWe OTEC plant producing aluminum would save 2×10^{13} m^3 of natural gas per year (Appendix D). Therefore, it is in the national interest to accelerate efforts to commercialize OTEC.

As mandated in the OTEC Act of 1980 (PL 96-320), the Administrator of NOAA will, after consultation with the Secretary of Energy, State and Federal government officials, and interested members of the general public, promulgate licensing regulations for commercial OTEC development. These regula-

tions will pertain to issuance, transfer, renewal, suspension, and termination of licenses and will establish procedures for the location, construction, ownership, and operation of OTEC facilities that are: (1) documented under U.S. law, (2) constructed, owned, or operated by U.S. citizens, (3) within the territorial seas of the United States, or (4) connected to the United States by pipeline or cable.

The legal regime is needed to ensure that commercial OTEC development will have due regard for: (1) the coastal marine and oceanic environment, (2) other coastal, marine, and high sea uses, (3) the overall interests of the United States, and (4) the rights and responsibilities of adjacent coastal states (e.g., coastal zone management).

1.2 OTEC LEGISLATION AND CONCEPT DEVELOPMENT

OTEC funding was initiated in 1972 by the National Science Foundation's Research Applied to National Needs (RANN) Program. Since 1972, OTEC development has passed several major program milestones:

- Operation of Mini-OTEC as the world's first successful closed-cycle OTEC plant (50 kilowatts (kWe), gross) to produce net energy at sea (Donat et al., 1980).

- Operation of the preoperational 1-MWe test platform (*Ocean Energy Converter*) for testing heat-exchanger materials and performing biofouling tests (DOE, 1979b; Sinay-Friedman, 1979).

- Construction of Stage 1 of the Seacoast Test Facility that will perform biofouling and corrosion experiments (ANL, 1980).

The Department of Energy (DOE) OTEC program, whose goal is to demonstrate the technological, economical, and environmental feasibility of OTEC powerplants (DOE, 1979a), is proceeding through interrelated subprograms of strategy and definition planning, engineering development and demonstration, and

technology development. The DOE OTEC program will culminate in the demonstration of at least one 40-MWe (net) pilot plant by 1986 (Sullivan et al., 1980).

In response to the progress being made in OTEC technology development, the U.S. Congress enacted two public laws to spur development of OTEC as a commercial energy technology for electrical power production: the OTEC Research, Development, and Demonstration Act (PL 96-310, signed into law July 17 1980) and the OTEC Act of 1980 (PL 96-320, signed into law August 3 1980). The complete texts of these laws are included as Appendix A.

The OTEC Research, Development, and Demonstration Act calls for the acceleration of OTEC technology development to provide a technical base to meet the following energy production goals:

- Demonstration by 1986 of at least 100 MWe of OTEC electrical capacity or energy product equivalent (approximately 0.04% of the projected U.S. energy demand).

- Demonstration by 1989 of at least 500 MWe of OTEC electrical capacity or energy product equivalent (approximately 0.2% of the projected U.S. energy demand).

- An average cost of OTEC electricity or energy-product equivalent that is competitive, by the mid-1990's, with conventional energy sources in the Gulf Coast region, islands, and possessions and territories of the United States.

- Establishment of a national goal of 10,000 MWe (10 gigawatts; GWe) of OTEC electrical capacity or energy product equivalent by the year 1999 (approximately 3% of the projected U.S. energy demand).

The OTEC development schedule to the year 2000 is shown in Figure 1-1 and reflects these energy production goals and the program milestones achieved to date. The current status of OTEC development is discussed in Appendix B.

The OTEC Act of 1980 directs:

- The Administrator of NOAA to establish a stable legal regime to foster commercial development of OTEC by (1) implementing a licensing program, (2) preparing an environmental impact statement covering each license application, (3) establishing a compliance monitoring program, and (4) conducting necessary environmental research on OTEC effects (Sections 102, 107, and 110).
- The Secretary of the department in which the Coast Guard is operating to establish and enforce procedures with respect to OTEC facilities and plantships to:

    - Promote safety of life and property at sea by lights and other warning devices, safety equipment, and designation of safety zones of appropriate size for OTEC operations. Permitted activities within such zones will be consistent with the purpose for which the zone was designated (Section 108(a)).

    - Prevent pollution of the marine environment (Section 108(a)).

    - Clean up any pollutants that may be discharged from OTEC plants (Section 108(a)).

    - Prevent or minimize any adverse impacts from construction and operation of OTEC plants (Section 108(a)).

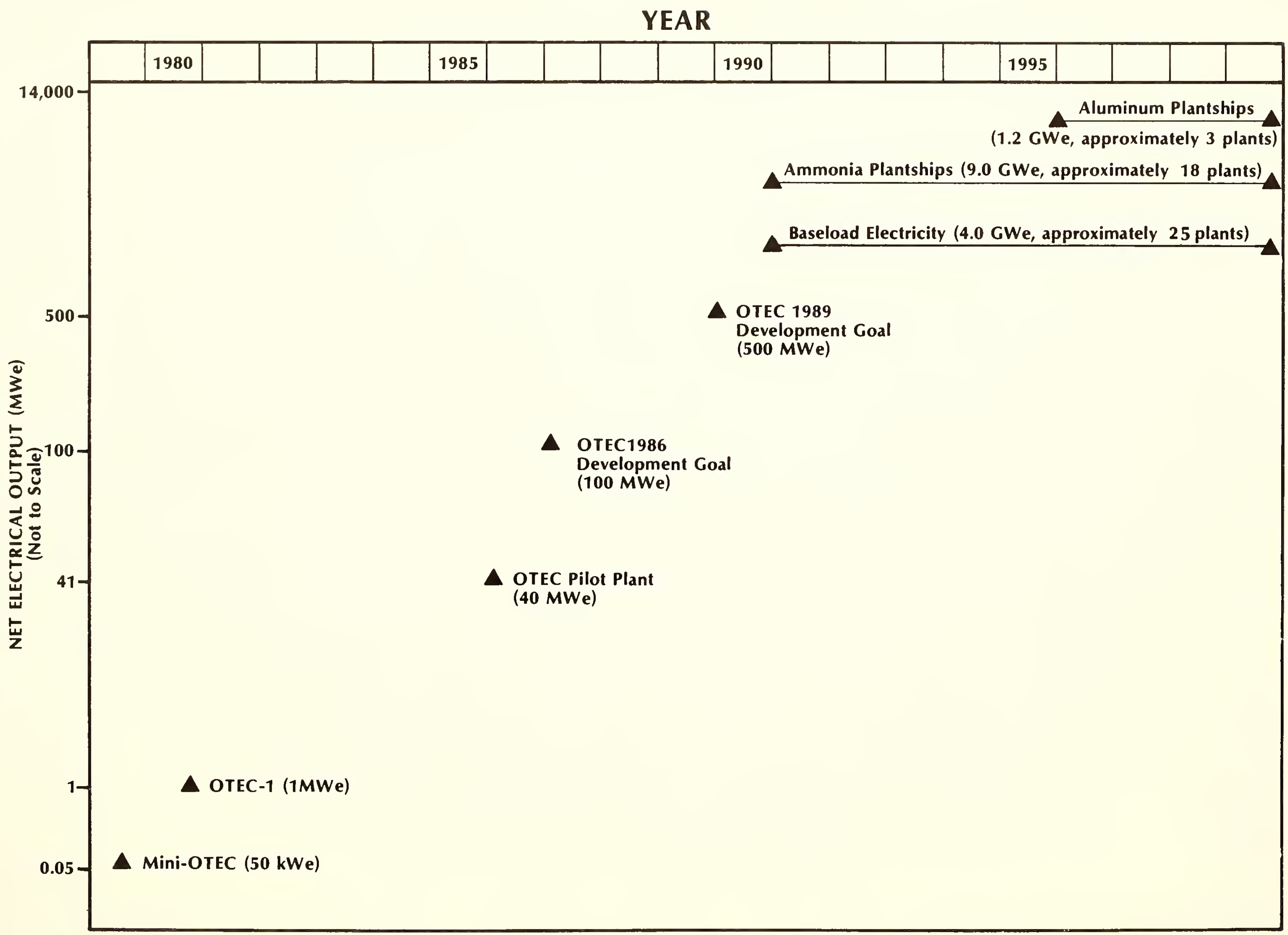


Figure 1-1. OTEC Development Schedule

- Ensure that the thermal plume of an OTEC plantship does not unreasonably impinge on and thus degrade the thermal gradient used by any other OTEC plantship or facility or the territorial sea or area of national resource jurisdiction of any other nation unless the Secretary of State has approved such impingement after consultation with such nation (Section 109(c)).

- The Administrator of NOAA and the Secretary of the department in which the Coast Guard is operating to share responsibilities for enforcement of regulations under the Act (Section 303(a)).

- The Secretary of State, in cooperation with the Administrator of NOAA and the Secretary of the department in which the Coast Guard is operating, to conduct international negotiations as necessary to assume noninterference between OTEC plants, safety of navigation, and resolution of other matters relating to OTEC plants that need to be resolved by international agreement (Section 402).

- The Secretary of Energy to establish and enforce standards and regulations necessary for safe construction and operation of submarine electrical transmission cables and equipment associated with OTEC plants (Section 404(a)).

1.3 TECHNOLOGY DESCRIPTION

OTEC employs the temperature differential between warm surface and cold deep-ocean waters to produce electric power. The electricity can be supplied to a local power grid or used for the production of energy-intensive products (e.g., ammonia, aluminum) that can be sent to domestic or foreign markets via conventional marine transportation methods. A large number of OTEC platform designs and power cycles have been studied. Although the designs differ, the engineering features that must be described for assessment of potential

environmental impacts or risk of credible accidents are similar. This section describes the various platforms and power systems that may be used for commercial OTEC plants. Because OTEC is presently a rapidly changing technology, description of specific plant components and details does not exclude technology which might change or become obsolete.

1.3.1 OTEC Plant Configuration

Specific descriptions of important OTEC plant components, including platform configurations, intake structures, discharge structures, and submarine transmission cables, are presented in the following subsections.

1.3.1.1 Platform Description - Several types of OTEC platform configurations have been studied, including the moored platform, bottom-resting tower, land-based plant, and grazing plantship. Following basic construction standards, all types of plants are expected to be designed to survive 100-year storms and other catastrophic events at the selected sites (e.g., earthquakes and extreme winds, waves, and currents).

Moored Platforms - Moored OTEC platforms are floating structures that are attached to the seabed by mooring lines. Moored platforms may have four basic hull configurations: rectangular, cylindrical, spherical, or disc; and may be surface-floating, semisubmerged, or totally submerged (Figure 1-2).

Riser cable systems may be used to link moored OTEC plants to high-voltage transmission cables on the seafloor. The riser cables must withstand stresses from current drag, strumming, platform motions, corrosion, and biofouling growth. The cables must be designed to withstand abrasion at the touchdown point caused by the cable scouring the bottom as the platform moves through its watch circle.

Bottom-Resting Tower - A bottom-resting tower (Figure 1-3) is a stationary platform upon which an OTEC plant may be built. Freestanding-articulated or derrick-type towers may be built in water depths less than 300 m. Guyed

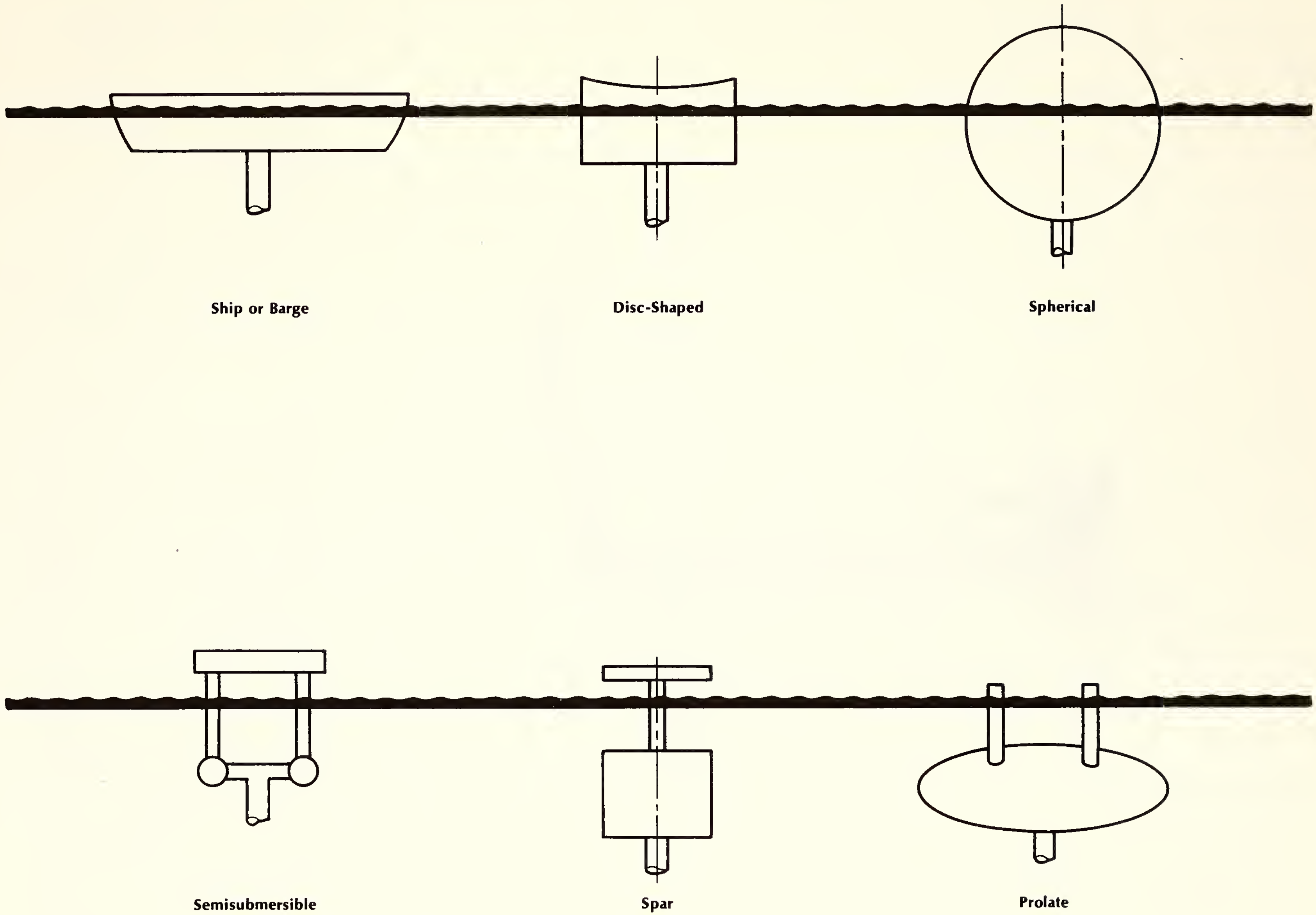


Figure 1-2. Moored OTEC Platform Designs
Source: DOE, 1978b

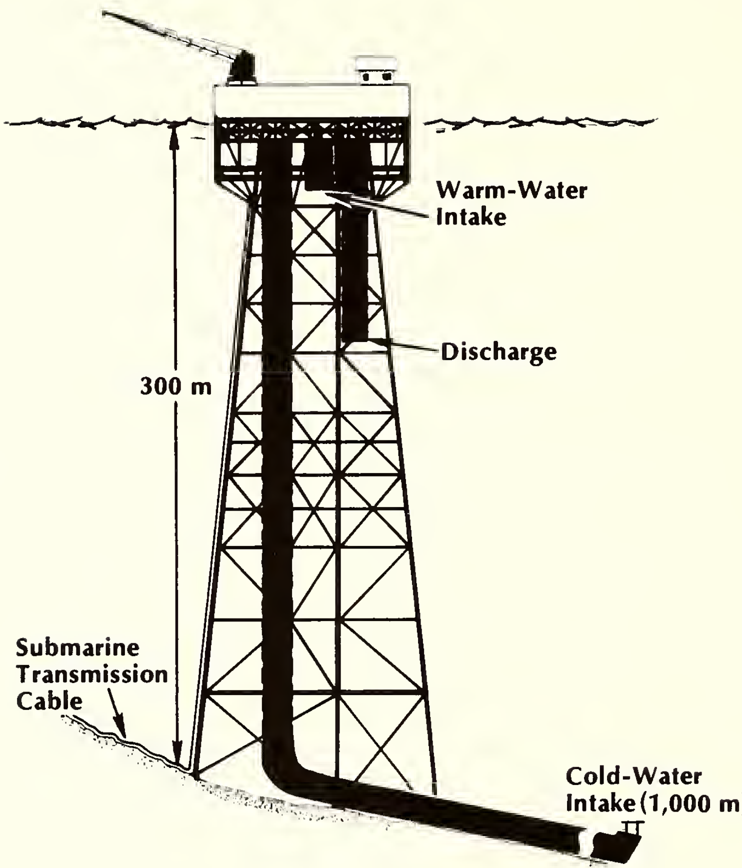


Figure 1-3. Typical Bottom-Resting Tower Design
Source: Sullivan et al., 1980

towers, which use guy lines for added stability, may be installed in water depths between 300 and 900 m. Shallow-water (less than 300 m depth) towers will use a cold-water pipe that extends from the platform to the bottom, and down the continental slope to the appropriate depth (Gibbs and Cox, 1979); deepwater (guyed) towers may incorporate the cold-water pipe in the tower legs. Towers built on the outer continental shelf may employ tunnels drilled through the seafloor to the appropriate depth instead of a conventional cold-water pipe (Green et al., 1980).

Land-Based Platforms - Land-based platforms (Figure 1-4) must be constructed at sea level to avoid large power losses due to the pumps (Brewer et al., 1979). The electricity produced could be linked directly into the power grid. The warm water may be taken in through either an excavated channel or through a pipe extending offshore. The cold-water intake may be a pipe extending from the plant or a tunnel drilled through the seafloor down the slope, to the appropriate depth. Due to plant configuration, warm and cold water used by the plant will probably be discharged separately through parallel pipes. It may be possible to discharge a portion of the nutrient-rich condenser effluent into nearshore lagoons or holding tanks for mariculture of marine plants and animals, such as seaweed and oysters.

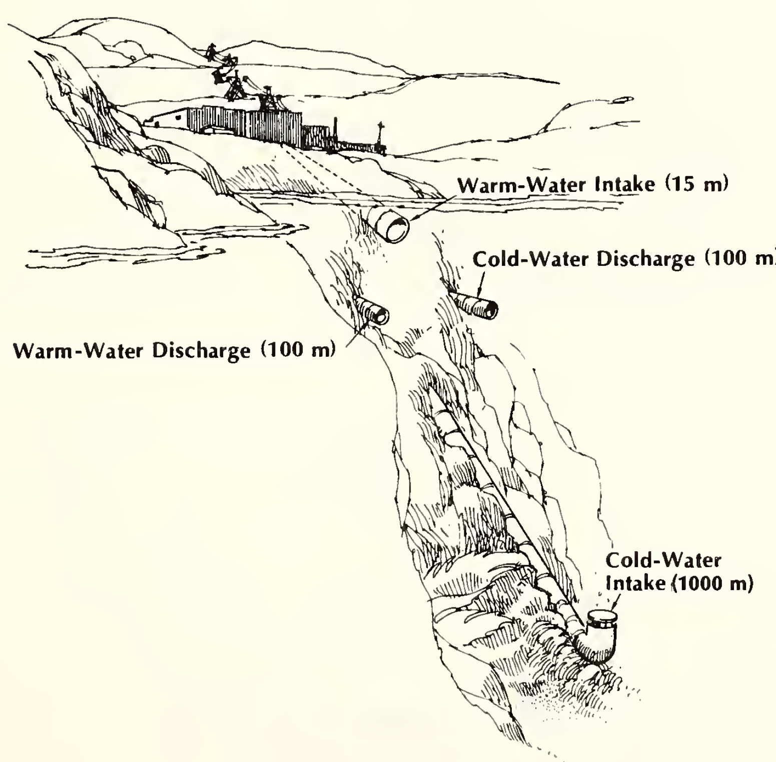


Figure 1-4. Typical Land-Based Design

Plantships - OTEC grazing plantships (Figure 1-5) will produce energy-intensive products (e.g., ammonia, aluminum). OTEC plantships will graze the OTEC thermal resource area, using a ship-like hull configuration constructed of prestressed reinforced concrete or steel. As shown in Figure 1-5, the warm-water pumps could be in sponsons near the corners of the platform, with the cold-water pipe attached midship and surrounded by the power system (George and Richards, 1980).

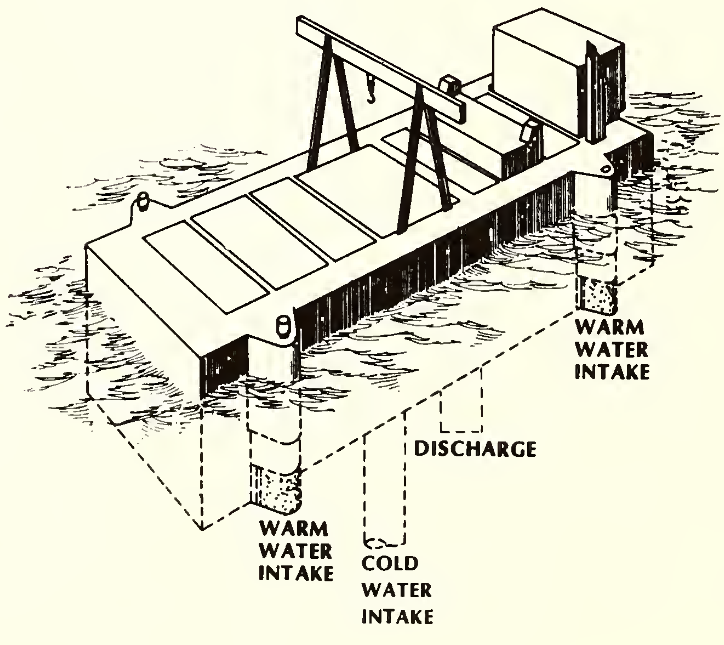


Figure 1-5. A Typical OTEC Plantship
Source: George et al., 1979

Plantships will house a plant capable of producing energy-intensive products (e.g., ammonia, aluminum), which will be delivered to market by ocean-going freighters or tankers. Ammonia (NH_3) will probably be produced

by the Haber process (DOE, 1977) in which pure hydrogen and nitrogen are combined in a 3 to 1 ratio. Hydrogen will be obtained by the electrolysis of desalinated seawater, while nitrogen will be extracted from the atmosphere by liquification and fractional distillation (DOE, 1977). A 500-MWe plant can produce approximately 5.2×10^5 metric tons of ammonia per year (George and Richards, 1980). The United States' projected demand for ammonia in 1981 is 1.9×10^7 metric tons (White, 1981).

Aluminum will be produced from alumina (brought to the plantship by freighter) using an electrolytic process. The conventional Hall process will probably not be used due to space requirements and platform motion problems. Two likely candidates for the electrolytic process are the drained-cathode Hall process and the new Alcoa process. These processes have a higher energy efficiency, require less deck area, and are tolerant of platform motions (Jones et al., 1980). In the drained-cathode Hall process, alumina is dissolved in cryolite and reduced to form molten aluminum. The Alcoa process involves the electrolysis of aluminum chloride, which is formed by a prior reaction using alumina (Mark, 1978). A 400-MWe plantship could produce approximately 3×10^5 metric tons of aluminum yearly (Jones et al., 1980), resulting in the release of approximately 3.5×10^5 metric tons of carbon dioxide per year. The United States' projected demand for aluminum in 1981 is 5.0×10^6 metric tons (St. Marie, 1981).

1.3.1.2 <u>Intake Structure Description</u> - OTEC plants require immense volumes ($10\ m^3\ sec^{-1}\ MWe^{-1}$) of warm and cold water for power production. The warm-water intake will withdraw water from the upper 50 m of the water column at velocities ranging from 10 to 350 cm sec^{-1} (Sullivan and Sands, 1980b). The cold resource water will be transported from below 500 m to the plant through either a single large pipe or several smaller pipes. A single cold-water pipe, constructed of concrete, steel, fiberglass, polyethylene, or nylon fiber neoprene will have a diameter of approximately 10 m for a 40-MWe plant, 15 m for a 100-MWe plant, and 30 m for a 400-MWe plant.

The warm and cold water withdrawn by an OTEC plant must be screened to prevent intake of materials that could clog the heat exchangers. Bar

screens, consisting of vertical parallel bars positioned over the intake, will be used at the warm- and cold-water intake openings to prevent passage of very large objects. Fine-meshed screens will not be placed over the cold-water intake because screen maintenance at great depth is not feasible. Thus, either static (fixed wire-mesh) or traveling screens will be located in sumps immediately before the condensers to remove materials that could clog the heat exchangers. Screen mesh sizes are generally half the heat exchanger tube diameter, or distance between the plates.

Land-based plants can use conventional intake configurations. The cold-water pipe will extend to depth and use the same screening methods mentioned above. The warm-water intake may be pipes or a channel. The channel intake may use screens at several different locations to minimize the number of organisms impinged against any one screen.

OTEC warm- and cold-water intakes may be bellshaped to reduce flow velocities, or may employ velocity caps, which produce horizontal flow fields much more readily sensed and avoided by fish than vertical flows (Hansen, 1978). In addition, there are a large number of auxiliary devices that may be incorporated into OTEC systems for lessening the number of organisms withdrawn by the warm-water intakes. Several fish-protection systems may be employed, including: (1) fish-collection and removal devices, (2) fish-diversion barriers, and (3) fish-deterrence systems.

1.3.1.3 Discharge Structure Description - A commercial OTEC plant may discharge the warm and cold water at or near the thermocline to prevent degradation of the thermal resource. Several different discharge configurations have been considered, including mixed and separate discharges that release either horizontally or vertically. Mixed discharges will dilute nutrient-rich deep-ocean waters with nutrient-depleted surface waters, and will minimize the temperature difference between the discharge plume and the surrounding waters. Due to water density differences, mixed-discharge waters will stabilize at greater depths than the separate warm-water discharge and

at shallower depths than the cold-water discharge. A vertical discharge structure injects the plume deep into the water column, potentially limiting recirculation and nutrient enrichment in the photic zone. A horizontal discharge structure produces slightly larger dilutions than vertical discharges (Ditmars and Paddock, 1979).

1.3.1.4 Protective Hull Coatings - To retard the buildup of macrofouling on hull surfaces, which adds additional weight and drag to the platform and increases the potential for component destruction by boring organisms, protective hull coatings may be applied. Toxic coatings are not practical for heat exchanger surfaces because their thickness interferes with heat transfer. Protective hull coatings may incorporate heavy metal oxides, organic compounds, or thermoplastic paints as their toxic constituent.

Protective hull coatings consist of a matrix containing a soluble toxic constituent: either the toxic constituent diffuses out of the matrix, or the entire coating gradually erodes to expose a fresh surface. Oxides of copper, mercury, and zinc are often used. However, toxic metal oxides require a protective primer coating when applied to metallic structures. Another consideration with regard to heavy metal oxides is the Federal government restriction of some paints (e.g., those based with mercury) because of potential environmental effects (Jacoby, 1981).

Toxic organometallic compounds such as organotin, organolead, and organotin fluorides are generally more effective protective coatings than heavy metal oxides. The biocidal properties of these compounds have been demonstrated in the paper industry and in antifouling coverings (Luijten, 1972). Montemarano and Dyckman (1973) and Castelli et al. (1975) reported that organometallic coatings have longer periods of effectiveness, due primarily to their constant leaching rate. Organometallic coatings leach approximately one order of magnitude slower than heavy metal oxides (Montemarano and Dyckman, 1973); no protective primer coats are needed with organometallic coatings.

1.3.1.5 Electricity Transmission Cables - OTEC plants may supply baseload electricity to electrical grids via submarine transmission cables. Moored plants require both riser cables and bottom transmission cables, while bottom-resting towers require only bottom cables. Two types of submarine transmission cables being considered include the self-contained oil- or gas-filled laminated dielectric cable and the extruded dielectric cable (Garrity and Morello, 1979; Pieroni et al., 1979). Because of cost considerations, cables probably will lie atop the seafloor, except in depths shallower than 100 m where they could be embedded 2 to 3 m into the substrate to avoid interference with other marine activities and to avoid stresses related to wave-induced forces. Cables may be imbedded at depths greater than 100 m where their presence on the substratum would interfere with deep-ocean uses such as trawling. Oil-filled dielectric cables have been used successfully in traditional submarine cable crossings. However, no high-voltage power cables have been laid to date at depths greater than 550 m (Pieroni et al., 1979).

1.3.2 Power-Cycle Description

This EIS considers all major power-system designs being considered for commercial OTEC plants, including closed-cycle, open-cycle, hybrid-cycle, mist-flow systems, and foam systems. Although the closed-cycle system has received the most study and use to date, the other power cycle systems are being evaluated for possible second-generation application, as warranted by technological developments and analyses. A brief description of each of the power cycles is presented in the following subsections.

1.3.2.1 Closed-Cycle OTEC System - In the closed-cycle OTEC system, warm water is pumped through a heat exchanger containing a working fluid. The warm water vaporizes the working fluid, which drives a turbine and provides electrical power. Once through the turbine, the working fluid vapor passes through another heat exchanger where it is condensed using cold seawater. The condensed working fluid is then pumped back into the warm-water heat exchanger for reuse (Figure 1-6).

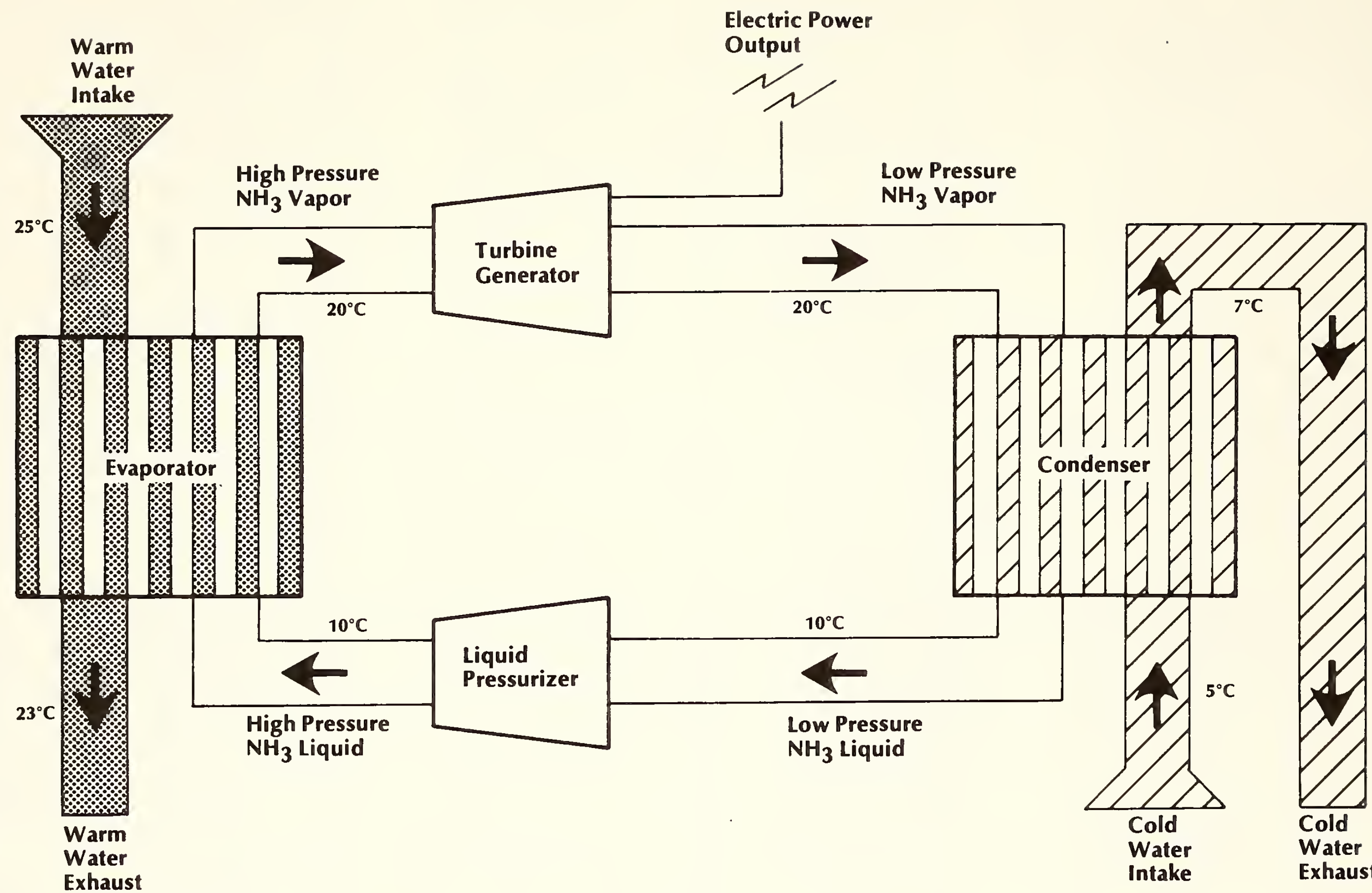


Figure 1-6. Schematic Diagram of a Closed-Cycle Power System
Source: Adapted from DOE, 1979a

The volumes of warm and cold water required for powering closed-cycle OTEC plants are variable, depending on the adequacy of the thermal resource gradient and efficiency of the heat exchangers and pumps. The volume of water required decreases as the heat exchanger efficiency and the thermal resource increases. Assuming a conservative thermal resource gradient of $20^{o}C$, the volumes of warm and cold water required for powering 40-, 100-, and 400-MWe closed-cycle OTEC plants are listed in Table 1-1. Based on these flow rates, a 400-MWe plant would require a volume of water equivalent to 20% of the average flow of the Mississippi River.

TABLE 1-1
INTAKE AND MIXED DISCHARGE FLOW SUMMARY (m^3 sec^{-1})

Intake/Discharge	Closed-Cycle		
	40-MWe	100-MWe	400-MWe
Warm Water Intake	200	500	2,000
Cold Water Intake	200	500	2,000
Mixed Discharge	400	1,000	4,000

The candidate working fluids most likely to be used in closed-cycle heat exchangers include ammonia, Freon 11, Freon 22, methyl chloride, methylene chloride, nitrogen dioxide, methyl formate, methyl amine, and ethyl amine. The Federal regulatory standing, physical characteristics, and human toxicity of these working fluids are listed in Table 1-2.

A major consideration in choosing a working fluid is the amount of heat exchanger surface area required per kilowatt of net power produced. Ammonia has been found to be the most cost effective (Coffay and Horazak, 1980) and require the least amount of heat exchanger surface area (Owens, 1978). Estimated amounts of ammonia working fluid range between 200 and 1000 m^3 for a 40-MWe plant to 10,000 m^3 for a 400-MWe plant.

TABLE 1-2. CHARACTERISTICS OF CANDIDATE OTEC WORKING FLUIDS

Fluid	Physical State* (20°C)	Federal Regulation Standing[a]	Water Solubility* (in 100 ml H_2O)	Flammability**	Explosion Hazard**	Disaster Hazard	OSHA[d] 8-Hour Exposure Limits (ppm)	Human Toxicity**,[e]	Carcino-genicity**
AMMONIA	Gas	HAZARDOUS SUBSTANCE	90 g (0°C)	671°C[b]	MODERATE (when exposed to flame)	MODERATELY DANGEROUS (emits toxic fumes when exposed to heat)	50	HIGH	NONE
FREON 22	Gas	Not regulated	INSOLUBLE	632°C[b]	No Information	DANGEROUS (emits highly toxic fumes when heated to decom-position or on contact with acid or acrid fumes) Atmospheric release may contribute to potential degradation of the ozone layer.	No Information	LOW	NONE
FREON 11	Liquid	Not regulated	INSOLUBLE	No Information	Reacts violently with aluminum	DANGEROUS (emits highly toxic fumes of fluorides and chlorides when heated to decomposition) Atmospheric release may contribute to potential degradation of the ozone layer.	No Information	LOW	NONE
METHYL CHLORIDE	Gas	TOXIC POLLUTANT	400g	632°C[b] <0°C[c]	MODERATE (Reacts violently with aluminum)	DANGEROUS (emits highly toxic fumes when heated to decom-position; reacts vigorously with oxidizing materials)	100	MODERATE	NONE
METHYLENE CHLORIDE	Liquid	TOXIC POLLUTANT	2g(20°C)	615°C[b]	None under ordinary conditions	DANGEROUS (emits highly toxic fumes when heated to decomposition)	500	MODERATE	NONE
NITROGEN DIOXIDE	Gas	HAZARDOUS SUBSTANCE	7g(0°C)	No Information	Reacts violently with aluminum	DANGEROUS (emits highly toxic fumes when heated to decom-position, reacts with water or steam to produce heat and corrosive fumes)	5	HIGH	NONE

TABLE 1-2. Characteristics of Candidate OTEC Working Fluids (Continued)

Fluid	Physical State*† (20°C)	Federal Regulation Standing[a]	Water Solubility*† (in 100ml H_2O)	Flammability**	Explosion Hazard**	Disaster Hazard	OSHA[d] 8-Hour Exposure Limits†† (ppm)	Human Toxicity**,[e]	Carcino-genicity**
METHYL FORMATE	Liquid	Not Regulated	30g (20°C)	465°C[b] -2°C[c]	MODERATE (when exposed to heat or flame)	DANGEROUS (emits toxic fumes when exposed to heat or flame; reacts with vigorously with oxidizing materials)	100	MODERATE	NONE
METHYL AMINE	Gas	Not Regulated	807g (12°C)	430°C[b] 0°C[c]	MODERATE (when exposed to spark or flame)	DANGEROUS (reacts vigorously with oxidizing materials)	10	MODERATE	NONE
ETHYL AMINE	Liquid	Not Regulated	SOLUBLE	385°C[b] <-17°C[c]	No Information	DANGEROUS (reacts vigorously with oxidizing materials)	10	HIGH	NONE

a - Clean Water Act, 1977;
b - Autoignition temperature
c - Flash point
d - Occupational Safety and Health Administration
e - Low - causes readily reversible tissue changes which disappear after exposure ceases.
- Moderate - may cause reversible or irreversible changes to exposed tissue, no permanent injury or death.
- High - capable of causing death or permanent injury in normal use; poisonous.

SOURCES: * - Holtzclaw, 1981
† - Hodgman, 1959
** - Sax, 1979
†† - United States Department of Labor, 1971.

Closed-cycle heat exchangers may be of two designs: tube-in-shell or plate. The tube-in-shell configuration (Figure 1-7) consists of many parallel tubes with their ends mated to a flat tube sheet. A shell encloses a bundle of these tubes between the sheets. Seawater is circulated inside the tubes, with the working fluid applied to the outside of the tubes. In this design, approximately 9.3 m^2 of heat exchanger surface is required for each kilowatt capacity of the OTEC plant (DOE, 1978c). The plate configuration (Figure 1-8) consists of a series of thin metal plates sealed together in pairs, with open spaces between each pair through which the working fluid can circulate. In the plate design, approximately 7.1 m^2 of heat exchanger surface is required for each kilowatt capacity of the OTEC plant (Rowan, 1980).

Various materials have been suggested for use in OTEC heat exchangers; the most likely candidates are commercially-pure titanium, aluminum alloys, and stainless steel alloys. Titanium was used in Mini-OTEC (Donat et al., 1980) and OTEC-1 (Sinay - Friedman, 1979); however, it is expensive and limited in

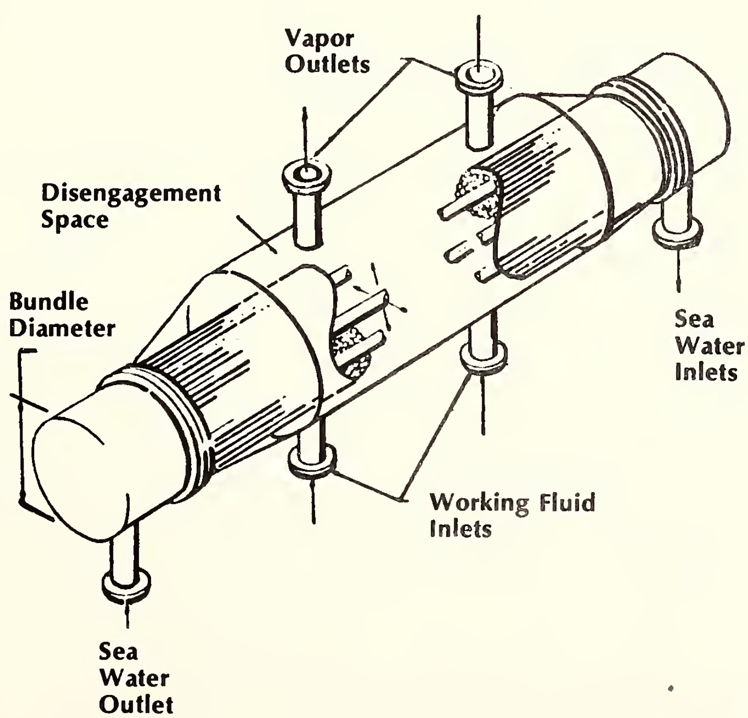


Figure 1-7. Tube-in-Shell Heat Exchanger
Source: Sands, 1980

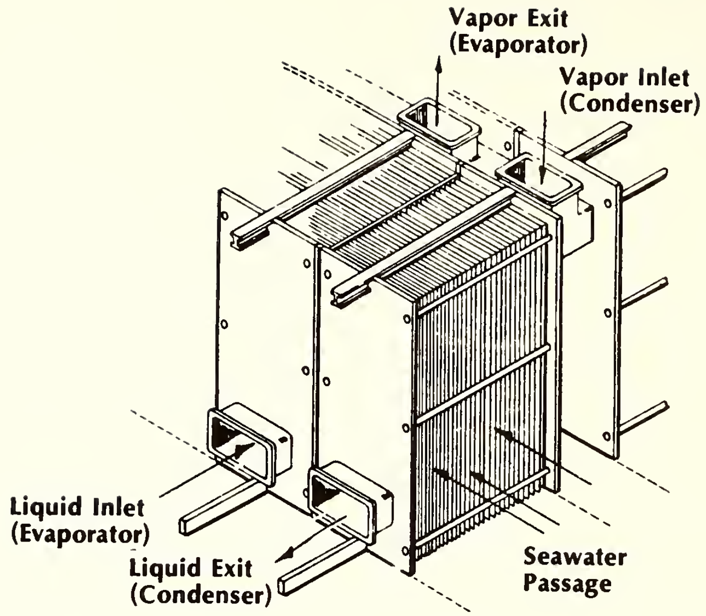


Figure 1-8. Plate-Type Heat Exchanger
Source: Berndt and Connell, 1978

supply. Aluminum alloys are cheap and abundant but have the possible drawback of a higher corrosion rate in seawater and ammonia than titanium. Stainless steel alloys would also be suitable since stainless steel is easily formed, readily available, and has adequate thermal conductivities.

The heat transfer efficiency of the heat exchangers, which must be maintained above minimum specifications for optimal plant operation, is greatly reduced by biofouling. To control fouling, a combination of techniques must be used to maintain heat-exchanger surfaces at optimal efficiency. Two major techniques for biofouling control include chemical and mechanical methods. Chemical methods are usually used to slow biofouling rates, but do not remove the material. Mechanical methods are used as necessary to remove the biofoulants.

Of the chemical methods, chlorination is the most viable method for use in commercial OTEC plants due to its low cost and ease of preparation. Chlorine could be generated electrolytically from seawater in commercial OTEC plants

to eliminate transport, storage, and handling of this hazardous gas. Other possible chemicals for the control of biofouling include chlorine dioxide, chlorine dioxide plus chlorine, bromine, bromine chloride, and ozone. These biocides are from two to ten times more expensive than chlorine (Sands, 1980).

Mechanical methods are limited to use in tube-in-shell heat exchangers (Hagel et al., 1977). Two mechanical systems have been designed: the Amertap-ball and M.A.N. brush systems. The Amertap-ball system cleans heat exchanger tubes using pliable foam rubber balls which are slightly larger in diameter than the heat exchanger tubes. Amertap-balls continuously circulate through the tubes removing slime and fouling layers from heat exchanger surfaces. The M.A.N. brush system consists of cylindrical, tufted brushes in a plastic cage, which scrub the deposits off heat exchanger walls as the brushes are pumped back and forth through the tubes by reversing the flow direction of the seawater.

Other biofouling control/removal methods being considered for commercial OTEC plants include ultrasonics, abrasive cleaning, and thermal shock. Further research is required to demonstrate the feasibility of ultrasonics for OTEC plants. Abrasive cleaning is presently not practical for commercial OTEC plants because of the large quantities of slurry medium required; the entire U.S. annual production of diatomaceous earth (the most suitable abrasive cleaning material) would be needed to make a one percent slurry for a six-hour cleaning cycle of a 400-MWe OTEC plant (Sands, 1980). Thermal shock, a method commonly used in conventional power plants, recirculates heated effluent through the heat exchangers to control biofouling growth. OTEC plants could achieve the temperatures required for thermal shock by accepting a seven percent parasitic power loss (Westinghouse, 1978).

1.3.2.2 <u>Open-Cycle Design</u> - The open-cycle OTEC system operates in much the same way as the closed-cycle system, except that seawater is used as the working fluid, eliminating the need for heat-exchanger surfaces. Warm surface seawater flows into a partially evacuated evaporator, where the lowered pressure changes the seawater to steam (Figure 1-9). The steam

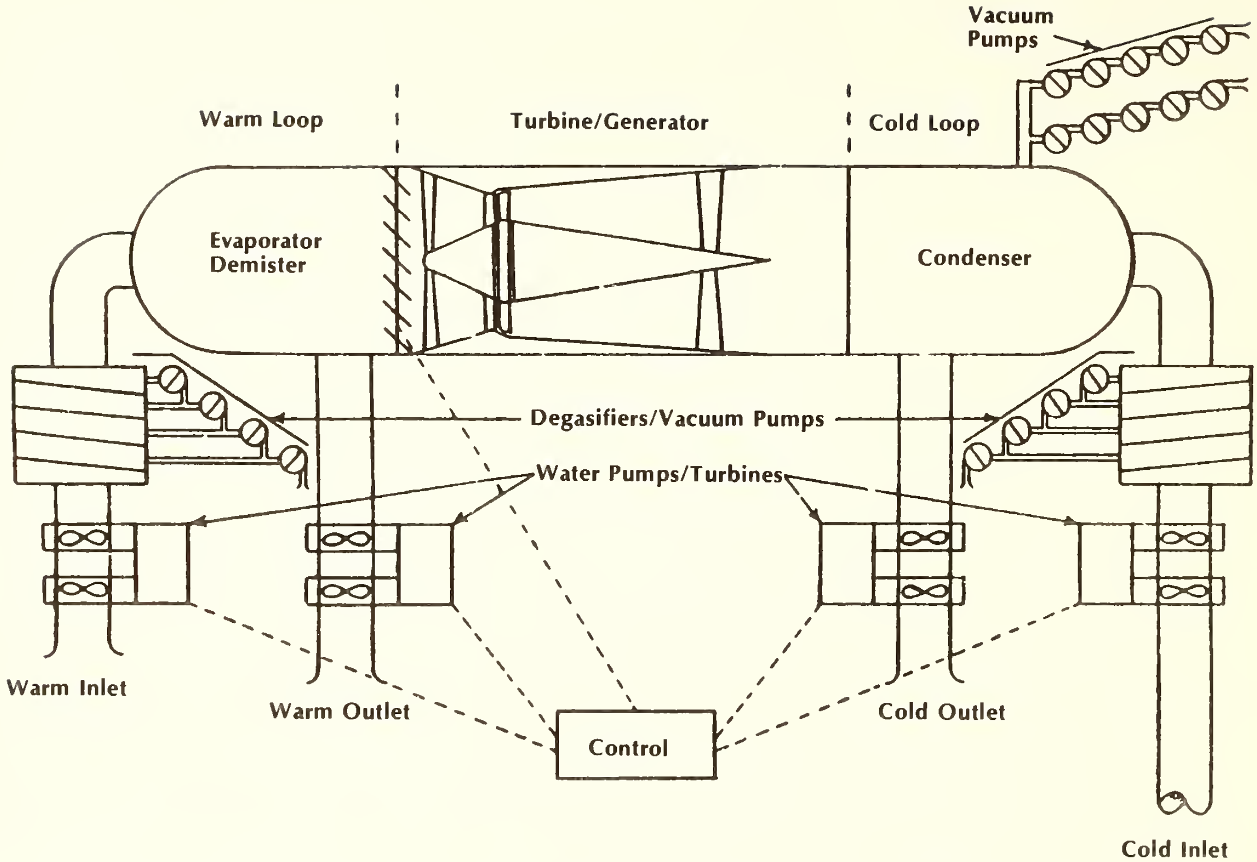


Figure 1-9. Schematic Diagram of an Open-Cycle OTEC Power System
Source: Watt et al., 1977

passes through a turbine, providing power for the plant, and is then condensed by cold seawater (DOE, 1978b). A 40-MWe open-cycle OTEC plant will require 200 m^3sec^{-1} of warm water and 160 m^3sec^{-1} of cold water (Watt et al., 1977). Approximately one percent of the warm water entering the evaporator is vaporized to steam allowing freshwater to be produced as a byproduct if the steam is condensed using heat exchangers instead of direct contact spray of cold seawater. Biofouling control measures, as described for the closed-cycle design, must then be considered to maintain heat exchanger efficiency. Freshwater production increases the salinity of the unvaporized warm water by less than one percent at the discharge point.

1.3.2.3 Hybrid Design - Hybrid-cycle OTEC plants (Figure 1-10) combine features from both the closed- and open-cycle systems. Hybrid plants flash-vaporize warm seawater in partially evacuated evaporators. The resulting

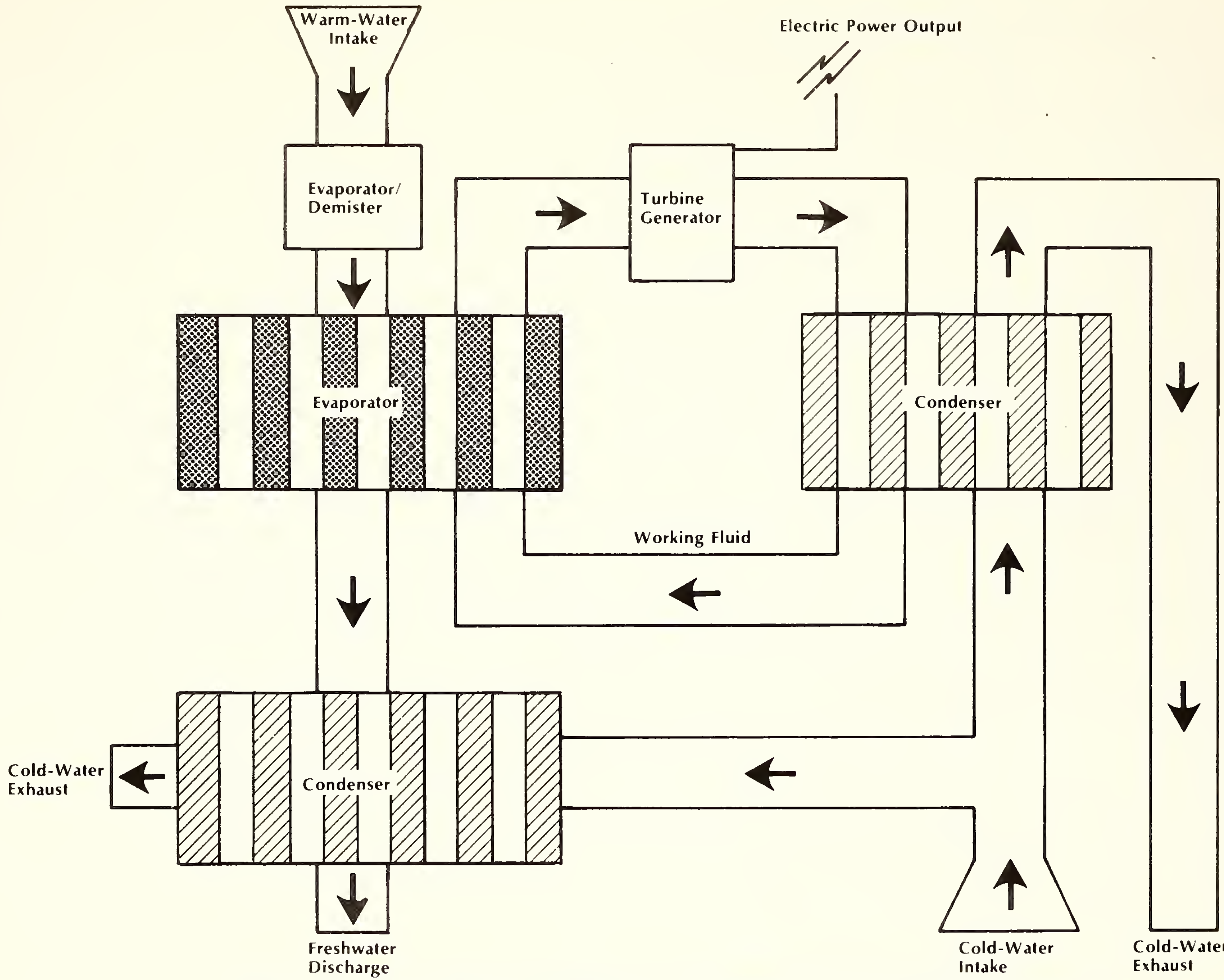


Figure 1-10. Schematic Diagram of a Hybrid-Cycle OTEC Power System

vapor is used to evaporate a second working fluid, which then performs as in the closed-cycle OTEC system. Freshwater may be produced, as in the open-cycle, if the vaporized warm seawater is condensed using heat exchangers instead of direct contact spray of cold ocean water (Charwat et al., 1979). Biofouling control measures, as described for the closed-cycle design, must then be considered to maintain heat exchanger efficiency.

1.3.2.4 Mist-Flow Design - The mist-flow design (Figure 1-11) is a variation of the open-cycle power system. Warm water is withdrawn near the surface, allowed to fall down a penstock, and passed over a turbine producing electricity. The warm water is then sprayed into a low-pressure chamber, forming a mist, which rises to the top of a duct. Here, the mist is condensed by cold seawater and discharged (Ridgway, 1977). A 400-MWe mist-flow plant will utilize 520 m^3sec^{-1} of warm water and 1,560 m^3sec^{-1} of cold water (Ridgway, 1980). Fresh water may be a byproduct of the mist-flow design, as in the open-cycle design, if heat exchangers are used to condense the mist instead of a direct contact spray of cold seawater. Biofouling control measures, as described for the closed-cycle design, must be considered to maintain heat exchanger efficiency.

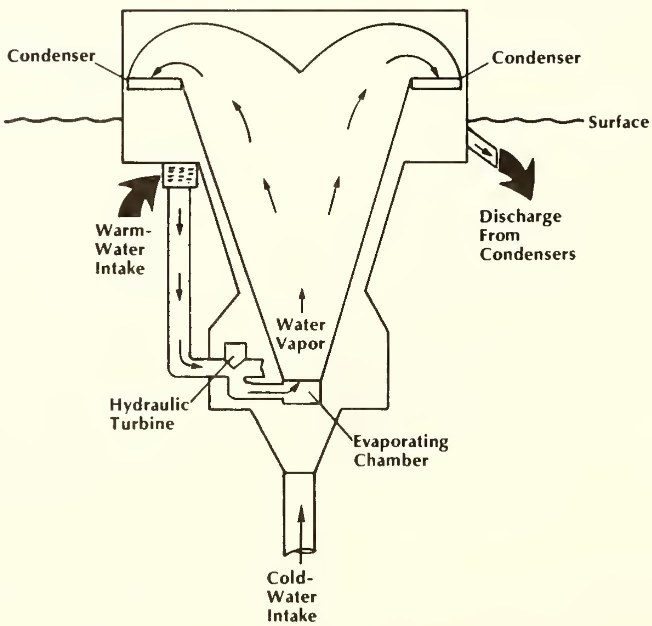


Figure 1-11. Schematic Diagram of a Mist-Flow OTEC Power System
Source: Ridgway, 1977

1.3.2.5 Foam Design - The foam power cycle (Figure 1-12) is a variation on the open-cycle power design. Warm seawater is mixed with a foam-promoting, biodegradable surfactant and introduced into a low-pressure chamber, where the warm seawater flash-vaporizes and large amounts of foam are formed. The foam is drawn upward to the top of the chamber, condensed by cold seawater, and allowed to fall through pipes leading to a hydraulic turbine. After passing over the turbine and generating electricity, the condensed seawater-surfactant mixture is discharged into the environment (Zener, 1977). A 400-MWe foam plant will utilize approximately 300 $m^3 sec^{-1}$ of warm water and 1200 $m^3 sec^{-1}$ of cold water (Zener, 1981).

1.4 DEPLOYMENT SCENARIO

The development of OTEC will probably progress from small (10- to 40-MWe) modular demonstration platforms to large-scale commercial plants (100- to 400-MWe). This development may encompass closed-cycle, open-cycle,

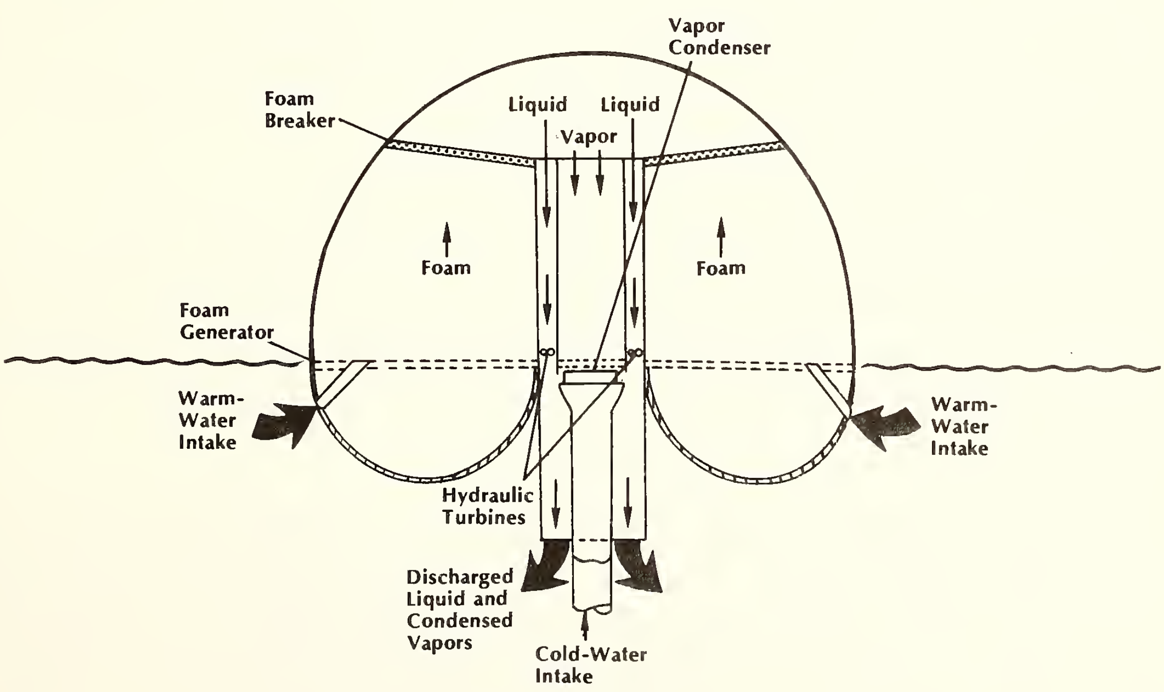


Figure 1-12. Schematic Diagram of a Foam OTEC Power System
Source: Zener, 1977

hybrid, mist-flow, and foam systems installed in moored, bottom-resting tower, land-based, or grazing plantship configurations.

Several OTEC deployment scenarios have been developed to the year 2020 (General Electric, 1977; Jacobsen and Manley, 1979). The scenario in this EIS combines the results of these studies, present and future technology, electrical demands, and the goals of the OTEC Research, Development, and Demonstration Act (PL 96-310) to provide an outline for baseload electricity and industrial plantship development for the year 2000.

1.4.1 Baseload Electricity Scenario

Commercial OTEC development will become viable earlier in U.S. tropical and subtropical island communities than on the mainland because OTEC-produced electricity will be cost-competitive in those areas sooner. Electricity costs range from two to eight times higher in island communities, which are almost totally dependent on imported oil (Sullivan et al., 1980). In addition, many island communities require freshwater, which is a beneficial byproduct of open-cycle, hybrid-cycle, and mist-flow OTEC plants. As OTEC designs are improved and conventional power costs continue to increase, OTEC power will become cost-competitive in mainland areas.

The island markets of Puerto Rico, the U.S. Virgin Islands, Hawaii, Guam, and the Northern Mariana Islands are expected to be major areas of OTEC development. After establishment of commercial OTEC plants in these island communities, large-scale commercialization will follow, based on entry into the U.S. Gulf Coast region.

The projected commercial OTEC development for the island markets through the year 2000 appears in Table 1-3. Twenty plants are projected to be in operation in Puerto Rico, the U.S. Virgin Islands, Hawaii, Guam, and the Northern Mariana Islands by the year 2000, with a total output of approximately 2100 MWe (2.1 GWe). Thirteen of these plants are projected for Puerto Rico and Hawaii. Because of the need for freshwater in island communities, a portion of the plants may be open-cycle, hybrid-cycle, or mist-flow systems.

TABLE 1-3

OTEC DEPLOYMENT SCENARIO FOR YEAR 2000

Region	Plant Type	Plant Size (MWe)	Number of Plants	Total Output (GWe)	Percent of Total Projected Need*
		BASELOAD ELECTRICITY			
Gulf of Mexico	Closed-cycle	400	5	2.0	<1
Puerto Rico	Closed-cycle	(400, 100, 40)	4	0.94	
	Open-cycle	40	2	0.08	
	SUBTOTAL-PUERTO RICO		6	1.02	5
Virgin Islands					
St. Croix	Closed- or Open-cycle	40	1	0.04	100
St. Thomas	Closed- or Open-cycle	40	1	0.04	100
	SUBTOTAL-VIRGIN IS.		2	0.08	100
Hawaii					
Oahu	Closed-cycle	(400,100)	3	0.60	80
Hawaii	Closed- or Open-cycle	40	1	0.04	50
Kauai	Closed-cycle	40	1	0.04	100
Maui, Lanai, and Molokai	Closed- or Open-cycle	40	2	0.08	90
	SUBTOTAL-HAWAII		7	0.76	80
Guam	Closed- or Open-cycle	(100,40)	3	0.18	100
Northern Mariana Islands	Closed- or Open-cycle	10	2	0.02	90
	BASELOAD TOTAL		25	4.06	
		AMMONIA PLANTSHIPS			
Gulf of Mexico	Closed-cycle	500	9	4.5	-
South Atlantic	Closed-cycle	500	9	4.5	-
	TOTAL AMMONIA PLANTSHIPS		18	9.0	
		ALUMINUM PLANTSHIPS			
Gulf of Mexico	Closed-cycle	400	1	0.4	-
South Atlantic	Closed-cycle	400	1	0.4	-
North Pacific	Closed-cycle	450	1	0.4	-
	TOTAL ALUMINUM PLANTSHIPS		3	1.2	
	GRAND TOTAL		46	14.26	

*See Appendix D

The Gulf of Mexico is a primary location for offshore OTEC power generation. The total projected power production for the Gulf of Mexico is dependent on the level of Federal incentives (Jacobsen and Manley, 1979). Five baseload plants, with a total output of 2.0 GWe, are projected to be in operation in the Gulf of Mexico by the year 2000, representing less than one percent of the total projected electrical need for that region (Appendix D).

The determination of specific plant locations within the thermal resource region is difficult to predict, as siting is dependent on a number of variables. The area of the Gulf of Mexico that has an adequate thermal resource for OTEC operation and proper depths for moored plants and bottom-resting towers is shown in Appendix C, Figure C-5. Around islands, moored, bottom-resting tower, and land-based plant siting will represent a compromise between optimal thermal resources in deep-ocean areas, maximum demand regions onshore, and engineering limitations.

1.4.2 Grazing Plantship Scenario

Plantships will generate electricity for onboard production of energy-intensive products, such as ammonia or aluminum. Plantships present a method of exploiting thermal resources located in areas either too deep or too far from shore for use of a stationary OTEC platform or in areas in which the thermal resource undergoes seasonal changes in location and magnitude.

The projected ammonia and aluminum plantship scenario is presented in Table 1-3. The demand for ammonia is expected to increase by 3 percent through the year 2000 (General Electric, 1977). If commercial plantship operations are initiated in 1990, eighteen 500-MWe plantships could meet the new demand for ammonia projected for the year 2000. General Electric (1977) projected a 4.9 percent annual growth for aluminum and assumed demonstration and deployment of three 400-MWe aluminum plantships by the year 2000.

Chapter 2

ALTERNATIVES TO THE PROPOSED ACTION

In establishing a legal regime that permits and encourages commercial OTEC development, it is essential to evaluate alternate regulatory approaches for minimizing adverse environmental impacts and protecting the interests of other ocean users. This chapter discusses the no-action alternative to the proposed action, describes the regulatory alternatives considered under the proposed action, and identifies the preferred alternative.

Regulations are necessary to establish a legal regime that reduces legal and regulatory barriers to construction and operation of commercial OTEC facilities and plantships. Reduction of institutional barriers was the primary reason that the U.S. Congress passed the OTEC Act of 1980 (PL 96-320). The Act legislatively-mandates a licensing system to be administered by NOAA that permits and encourages development of OTEC as a commercial energy technology, ensures that OTEC plants do not interfere with ocean thermal resources used by other OTEC plants, protects the marine and coastal environment, and ensures that commercial OTEC facilities and plantships licensed by NOAA comply with international treaty obligations of the United States.

No OTEC plant of commercial size has yet been constructed or operated. Many theoretical predictions have been made of the operating characteristics and potential environmental impacts of commercial OTEC plants, but the theoretical work has not been confirmed by actual experience. Consequently,

NOAA must devise a general regulatory approach which takes into account the possibility of unexpected operating characteristics or environmental impacts, while meeting the legislated goals for the regulatory system.

The alternatives to the proposed action considered in this document include the no-action alternative and various regulatory alternatives for minimizing adverse environmental impacts. Section 2.1 discusses the no-action alternative, which would result in not establishing a commercial OTEC legal regime. Section 2.2 discusses alternative regulatory approaches under the proposed action which would minimize or mitigate the major potential environmental effects identified in Chapter 4. Section 2.3 describes the preferred alternative.

2.1 THE NO-ACTION ALTERNATIVE

Under the no-action alternative, NOAA would not issue regulations to implement the OTEC Act of 1980. A decision to forgo issuance of regulations would place the Administrator of NOAA in violation of Public Law 96-320. Section 102(a) of the Act requires the Administrator to complete issuance of final regulations by August 3, 1981.

Adoption of the no action alternative would leave in existence many of the legal and regulatory uncertainties which the U.S. Congress intended to be resolved by passage of the Act and could discourage the commercial development of OTEC. Licensees would not be afforded the convenience of the one-step licensing regime provided by the legal regime, requiring that permits for OTEC plant ownership, construction, and operation be obtained from each involved Federal, State, and local agency. In addition, failure to implement the regulatory provisions of the Act could restrict Federal financial support for commercial OTEC development.

Discouraging commercial OTEC development could continue the dependence of the United States and its associated island territories, trust territories,

and commonwealths on imported oil and other energy sources, which pose greater environmental risks than OTEC. Figure 2-1 summarizes the magnitude of environmental effects associated with various electricity generating methods. Although the environmental effects associated with solar or geothermal powerplants are expected to be less than those from OTEC, OTEC is more environmentally acceptable than utilizing nuclear, oil, or coal-fired plants for power production.

Adopting the no-action alternative could discourage the development of industries that would construct, assemble, operate, and maintain OTEC plants. The implication of discouraging potential OTEC-related industries would be significant to high-unemployment areas, such as island communities and large depressed city areas, where most major shipyards are located. Construction, deployment, and support of OTEC plants could alleviate both long-term and short-term unemployment by providing various employment opportunities to local contractors and laborers. Francis et al., (1979) estimated that approximately 2,000 worker-years of shipyard employment would be required for the construction of a 40-MWe OTEC plantship.

If commercial OTEC development persisted in spite of legal obstacles and lack of financial support, existing regulations for controlling the use of the environment and preventing adverse environmental impacts would have to be used. Since existing regulations were not specifically prepared for commercial OTEC plants, adoption of the no-action alternative could: (1) cause existing regulations to be imposed that are not applicable to commercial OTEC plants' unique design and siting requirements, or (2) allow commercial OTEC plants to interfere with other ocean uses or cause significant environmental disturbances.

The United States is required by international treaties to ensure that its citizens respect the rights of citizens of other countries in conducting ocean activities. Development of OTEC as a commercial energy technology without the legal regime specified by the OTEC Act of 1980 could place the

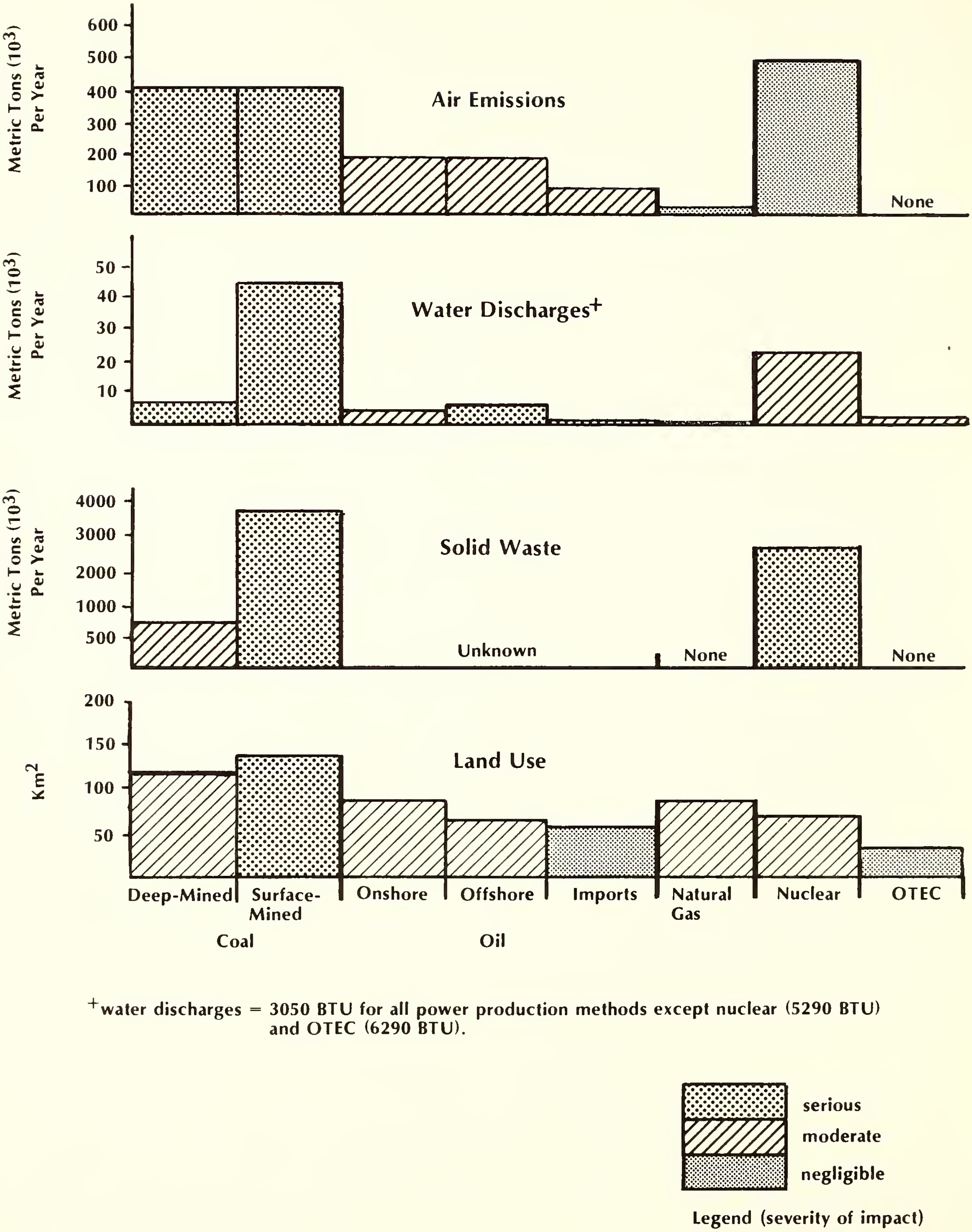


Figure 2-1. Comparative Annual Environmental Impacts (1,000 MWe Systems) From Various Power Production Methods
Source: Adapted from Council on Environmental Quality, 1973

United States in violation of its international treaty obligations and create a difficult international incident, in addition to causing environmental and socioeconomic damages.

In summary, the no-action alternative would allow legal and regulatory barriers to remain which could discourage or prevent development of a commercial OTEC industry. If an OTEC industry were to develop despite those barriers, no legal system would exist to protect the environment and the rights of other ocean users. For these reasons, NOAA does not favor implementing the no-action alternative.

2.2 ALTERNATIVES UNDER THE PROPOSED ACTION

The potentially significant environmental effects associated with the commercialization of OTEC technology are identified in Section 4.7 of this EIS, along with possible mitigating measures. These potentially significant effects include:

- Biota attaction/avoidance
- Organism entrainment
- Organism impingement
- Biocide release
- Nutrient redistribution
- Sea-surface temperature alterations

The magnitude of environmental disturbances associated with these issues will depend upon site-specific characteristics of the proposed OTEC site and the technological design of the plant. As a consequence, regulatory alternatives for minimizing environmental impacts from OTEC plants could range from detailed regulations, which cover all of the possibilities that may arise, to flexible regulations, which allow for site-specific license terms. This section evaluates alternative regulatory approaches and selects the approach which provides the maximum encouragement to commercial OTEC development while maintaining acceptable environmental quality. Section 2.2.1 describes the general siting and technology considerations for

mitigating environmental impacts and summarizes pertinent regulations presently existing for protecting the environment. Section 2.2.2 contrasts three alternate regulatory approaches for maintaining environmental quality.

2.2.1 General Considerations

2.2.1.1 Site Evaluation Considerations - OTEC sites may be of three types: (1) small (10 to 1,000 km^2) areas that encompass all plant activities, structures, and discharge plume effects; (2) large (1,000 to 10,000 km^2) areas that encompass multiple OTEC deployments; or (3) very large (greater than 10,000 km^2) oceanic regions for use by grazing plantships. The adequacy of a potential OTEC site will depend on the following principal environmental characteristics:

- Availability of an adequate thermal resource for continuous OTEC operation.
- Current velocities high enough to replenish the thermal resource and disperse the waters used by the plant, but not exceeding platform structure design criteria.
- Appropriately low frequency of occurrence of extreme meteorological conditions that exceed plant operation or survival limits.
- Appropriate geological and bathymetic conditions for moored and land-based plants.
- Compatibility with existing and potential ocean uses.

In general, OTEC operation sites must be chosen from identified candidate sites on the basis of minimizing interference with other major ocean use areas, such as shipping lanes, military zones, marine sanctuaries, ocean disposal sites, and commercially or ecologically sensitive areas. The impacts

on recreational activities and aesthetics must also be considered. The location of single or multiple OTEC plants should be chosen so that localized perturbations in water quality or other environmental conditions during initial discharge plume mixing are reduced to normal ambient seawater levels or to acceptable contaminant concentrations before reaching any beach, shoreline, marine sanctuary, or known geographically-limited fishery. In addition, OTEC operation sites must be evaluated on the basis of minimizing thermal interference between OTEC plants.

2.2.1.2 Intake and Discharge Structure Design - The design of OTEC intake and discharge structures directly influences the magnitude of impacts from organism entrainment, organism impingement, biocide release, and nutrient redistribution. Warm- and cold-water intake structure diameter, shape, depth, orientation, withdrawal velocity, screen configuration, screen mesh size, and ancillary structures (e.g., fish-return or -repelling systems) are important factors for directly or indirectly determining entrainment and impingement rates. OTEC discharge designs may include variations in the angle, velocity, and depth of discharge, the use of mixed or separate discharges, and the number of discharge ports. The design of OTEC discharge structures and the environmental characteristics of the site determine the discharge plume location within the water column, its behavior, and its rate of dilution, all of which determine the populations affected by biocide release and nutrient redistribution. Since commercial OTEC plants withdraw and redistribute immense volumes of water, it is extremely important to design intake and discharge structures to prevent unnecessary damage to important biological populations.

2.2.1.3 Biocide Release - Biocide release is a likely consequence of OTEC operation. Biocides are expected to significantly affect the local marine environment because of their toxicity to nontarget organisms and the large volumes that must be released to maintain OTEC heat exchanger efficiency. Therefore, biocide release from OTEC plants must be regulated to prevent unnecessary damage to ecologically-, commercially-, or recreationally-important populations.

Alternative biocide release control methods include limits on biocide concentrations and release schedules. The Federal Water Pollution Control Act, as amended, established the National Pollutant Discharge Elimination System (NPDES) to regulate point-source discharges. Several types of limitations can be incorporated into an NPDES permit: (1) technology-based permit limits that apply at the discharge point, (2) water quality standards, (3) discharge limitations based on toxicity data, or (4) use of the steam-electric industry guidelines (DOE, 1979c). In developing the best available technology to control the release of certain effluents, EPA states that greater emphasis will be placed on toxicity-based limits rather than technology-based limits, particularly if the latter are inadequate for toxicity elimination (DOE, 1979c). There are no established toxicity guidelines for organisms that occupy the OTEC resource area; however, studies currently underway at the Gulf Coast Research Laboratory will provide valuable information for the establishment of these guidelines (Venkataramiah, 1979).

At present, chlorine is the biocide-of-choice for maintaining heat exchanger efficiency. Two alternative methods for its release are: (1) continuous discharge of low concentrations of chlorine, and (2) intermittent discharge of high concentrations of chlorine. Continuous, low-level chlorination reduces the potential for acute impacts, but increases the number of organisms affected by chlorine impacts. Intermittent high-level chlorination causes acute and chronic effects only to those organisms in the vicinity of the discharge during chlorine release. Because of the reduction in environmental effects anticipated with intermittent chlorination schedules, EPA has allowed the discharge of chlorinated cooling waters from steam-electric generating plants at 0.2 mg liter^{-1} for a maximum of 2 hours per day (EPA, 1974). New chlorination discharge standards have been proposed for steam-electric generating plants and are scheduled for implementation in late 1981 (Wright, 1981).

2.2.1.4 <u>Existing Provisions for Maintaining Environmental Quality</u> - In general, compliance with the regulatory provisions contained in the Ocean

Discharge Criteria (40 CFR, Part 125), and other existing environmental regulations which may apply to commercial OTEC plants, should provide adequate environmental protection. The Ocean Discharge Criteria respond to Section 403(c) of the Federal Water Pollution Control Act and Amendments which called for guidelines for determining the degradation of the waters of the territorial seas, the contiguous zone, and the ocean. The promulgated Ocean Discharge Criteria allow the Administrator of the U.S. Environmental Protection Agency (EPA) to issue an NPDES permit for a discharge to such waters if, on the basis of available information, the discharge will not cause unreasonable degradation of the marine environment. Such a determination is based on:

- The quantities, composition, and potential for bioaccumulation or persistence of the pollutants to be discharged.

- The potential transport of such pollutants by biological, physical, or chemical processes.

- The composition and vulnerability of the biological communities which may be exposed to such pollutants, including the presence of unique species or communities of species, the presence of species identified as endangered or threatened pursuant to the Endangered Species Act, or the presence of those species critical to the structure or function of the ecosystem, such as those important for the food chain.

- The importance of the receiving water area to the surrounding biological community, including the presence of spawning sites, nursery/forage areas, migratory pathways, or areas necessary for other functions or critical stages in the life cycle of an organism.

- The existence of special aquatic sites including, but not limited to marine sanctuaries and refuges, parks, national and historic monuments, national seashores, wilderness areas, and coral reefs.

- The potential impacts on human health through direct and indirect pathways.

- Existing or potential recreational and commercial fishing, including finfishing and shellfishing.

- Any applicable requirements of an approved Coastal Zone Management plan.

- Such other factors relating to the effects of the discharge as may be appropriate.

- Marine water quality criteria developed pursuant to Section 304(a)(1).

2.2.2 Regulatory Alternatives Under the Proposed Action

NOAA has identified three possible general regulatory approaches under the proposed action: (1) detailed regulation of OTEC activities, (2) moderate regulation of OTEC activities, and (3) minimal regulation of OTEC activities. Each approach would require the licensee to perform monitoring of environmental effects of OTEC operation (as stated in Section 110(3) of the OTEC Act) and meet the requirements of the National Pollutant Discharge Elimination System (NPDES) and Ocean Discharge Criteria; however, the three approaches differ in the extent of regulation and the degree of plant design and siting flexibility afforded the licensee. Each of these alternative approaches is discussed in the following subsections.

2.2.2.1 Detailed Regulation of OTEC Activities - Under this approach, the regulations would contain detailed substantive provisions specifying design

of OTEC plant components and siting criteria. NOAA would have to conduct reviews of all aspects of the proposed OTEC plant in order to ensure full compliance with the regulations. The information required to be submitted with an application would have to be sufficiently detailed and would most likely necessitate completion of design of the proposed OTEC plant prior to preparation of the license application for submission to NOAA.

A licensee would have to demonstrate to NOAA compliance with all specific requirements contained in the regulations. The monitoring of environmental effects which the licensee is required to perform by Section 110(3) of the OTEC Act would provide NOAA with the information needed to determine whether some of its detailed regulatory requirements were stricter than necessary to accomplish the regulatory goal. Those regulatory requirements found to be too strict could then be relaxed.

Utilizing detailed regulations would require specifying intake and discharge structure designs that cause minimal environmental effects for all OTEC plant designs and representative siting environments. Insufficient information is available to establish these regulations because of the diversity in abundance, vertical and spatial distribution, and behavior of local biological populations and the variability of other oceanographic parameters. Since site- and species-specific considerations must be evaluated to design intake and discharge structures which cause minimal impacts, designation of specific designs may not maintain acceptable environmental quality in all cases. In addition, designated intake and discharge structure designs would be too rigorous for certain areas, thereby unnecessarily increasing plant construction costs and reducing flexibility of OTEC plant designers.

Utilizing the detailed regulatory approach would also require the establishment of standards for allowable biocide concentrations and release schedules based upon technology considerations, toxicity studies, or existing

guidelines. Although the established standards should be sufficiently low to prevent adverse environmental impacts, the detailed regulatory approach would not allow OTEC licensees the flexibility of siting plants in areas where slightly larger biocide releases would cause insignificant effects.

2.2.2.2 Moderate Regulation of OTEC Activities - Under the moderate regulation approach, the regulations would not contain detailed substantive provisions specifying design of OTEC plant components. The regulations would, however, contain specific guidelines and performance standards to ensure adherence to the overall regulatory goals. A license applicant would be required to demonstrate that his plant design and approach would meet each of the specific guidelines and performance standards included in the regulations. Guidelines and performance standards might relate to such matters as warm-water intake design, discharge plume behavior and dilution, and burial of pipelines and cables, where feasible. The information required to be submitted with an application would be less voluminous than under the detailed regulation alternative, but would have to include analyses and predictions of the proposed OTEC plant's performance standards. While this alternative would not require submission of a detailed design for the entire proposed OTEC plant, the information needed to demonstrate compliance with at least some of the guidelines and performance standards would probably not be available until at least part of the OTEC plant detailed design is completed.

The monitoring of environmental effects, which the licensee is required to perform by Section 110(3) of the OTEC Act, would provide NOAA with the information needed to determine whether some of its specific guidelines and performance standards were stricter than necessary to accomplish the regulatory goals, and would alert NOAA to additional areas in which specific guidelines or performance standards were needed.

Use of the moderate approach would result in NOAA establishing uniform guidelines and performance standards applying to all OTEC plants within a general ecosystem (e.g., nearshore, open-ocean). In some cases, the uniform guidelines and performance standards would restrict design options which might be environmentally-preferred for a particular OTEC plant or site. The

full consequences of such an instance would not be known at the time NOAA adopted the original set of guidelines and performance standards because there is no real-world experience with OTEC plants of commercial size on which to rely. The guidelines for intake and discharge design, biocide control strategies, and other aspects of OTEC under this alternative would have a generic environmental basis rather than applying to all OTEC siting environments.

The use of specific guidelines and performance standards as required by this alternative is the approach commonly used to regulate mature, stable industries in which many facilities exist and the nature of their technology and resulting environmental impacts are known. However, when applied to a nascent industry such as OTEC, this approach could have a limiting effect on the flexibility and experimentation which will be necessary to learn the designs which best meet the multiple goals of environmental protection, sound engineering, and economic construction and operation. Because monitoring would be required under all alternative approaches, and an alternative more suitable to the current early developmental stage of the OTEC industry exists, the moderate regulation alternative is not selected.

2.2.2.3 <u>Minimal Regulation of OTEC Activities</u> - Under the minimal regulation alternative, NOAA would use minimal guidelines and performance standards to conform to the goals and provisions of the OTEC Act of 1980. These guidelines will be based on minimum NPDES regulations, Ocean Discharge Criteria, and other applicable regulations as agreed upon by the Administrator of NOAA, the Environmental Protection Agency, and other pertinent responsible agencies.

Under the minimal regulation alternative, detailed environmental guidelines and performance standards would not be prescribed in advance, but would be developed for inclusion as terms and conditions of a license if they were deemed necessary by the Administrator to prevent adverse environmental impacts. The use of case-by-case license terms and conditions--rather than uniform regulations--to address significant environmental issues would

require NOAA to examine each applicant's assessment of the nature and relative magnitude of each type of problem which might occur as a result of construction and operation of the proposed OTEC plant. Only those problems which appeared to be significant would be analyzed in detail. The information submitted to NOAA in a license application would not depend upon completion of detailed design, but would need to include descriptions of the relevant operating features of the plant and an assessment of the potential impacts resulting from construction and operation.

Although the minimal regulation alternative results in maximum flexibility for plant design and operation, it also necessitates extensive monitoring to ensure environmental compatibility. The monitoring of environmental effects, which the licensee is required to perform by Section 110(3) of the OTEC Act, would alert NOAA to significant problem areas which might need to become the subject of future license terms and conditions.

Adoption of site-specific biocide regulations would allow the establishment of biocide concentration levels and release schedules for specific OTEC power systems and siting regions (i.e., nearshore, offshore). This approach would provide optimal flexibility to OTEC license applicants for designing OTEC plants and selecting operation sites while maintaining environmental quality. Employing the minimal regulatory approach, which would allow each OTEC plant to establish individual biocide release rates if subsequent monitoring demonstrates minimal environmental effects, might allow higher biocide release rates for a specific OTEC plant than the detailed or moderate regulatory approach.

Under the minimum regulation approach, NOAA would consider and respond to proposals made by license applicants, instead of prescribing standards for the applicant to follow. The flexibility afforded the applicant under this approach would allow the prospective OTEC plant owner to propose what he considers to be the best environmental and engineering design for the plant and to design a cost-effective means of mitigating or reducing adverse environmental impacts resulting from plant operation. The flexibility would allow

incorporation of new technology into OTEC plant design as the technology is developed, and provide for site-specific license terms and conditions to protect the environment.

Because monitoring is required in all three alternative regulatory approaches, and the minimal regulation alternative preserves the flexibility to deal effectively with site-specific environmental concerns, it is the preferred alternative. The minimal regulatory system would accomplish the goals of the OTEC Act of 1980 without interfering with technological innovations and responsible experimentation, which are part of the development of a new commercial power industry.

2.3 THE PREFERRED ALTERNATIVE

Minimal regulation of OTEC activities is the preferred alternative and has been chosen as NOAA's preferred general approach. It offers the greatest encouragement for creation of a commercial OTEC industry and realization of the resulting major environmental and economic benefits to the United States. The minimal regulation approach also provides the flexibility necessary to avoid artificial prejudgement of environmental protection measures at the current early stage in the development of OTEC technology. The preferred alternative will provide maximum protection to the environment by providing maximum flexibility to adapt to site-specific problems and characteristics, while still maintaining general provisions where appropriate. As such, it is considered to be the best approach to maintaining a legal regime that will effectively satisfy the requirements of the OTEC Act.

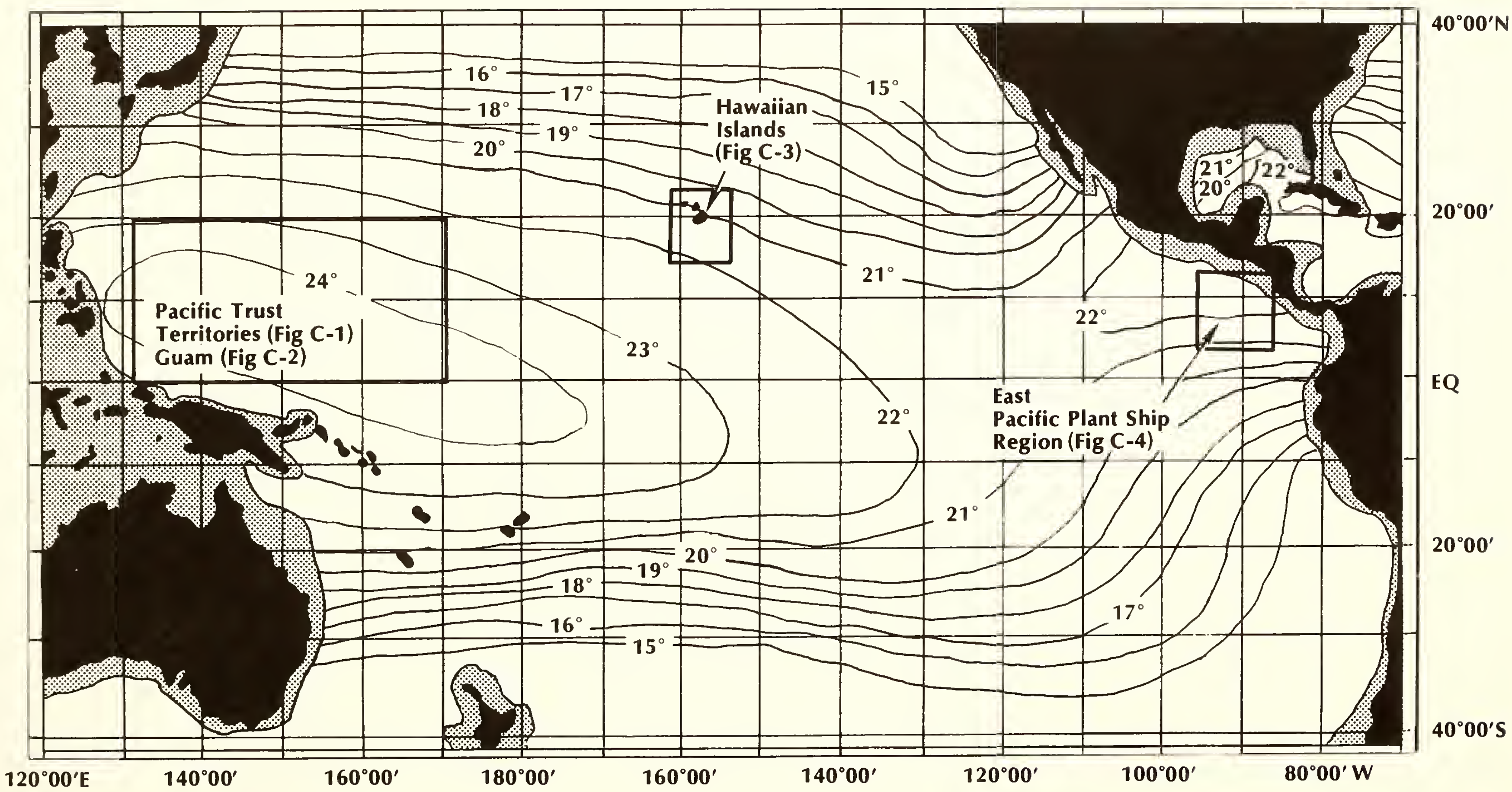
Chapter 3

AFFECTED ENVIRONMENT

> A generic description of the atmospheric, marine, coastal, and terrestrial environments within the OTEC resource area is critical for adequately assessing the environmental effects of commercial OTEC development. Typical environmental characteristics which facilitate the assessment of impacts are presented. Areas having environmental characteristics that deviate significantly from the typical are described.

This chapter provides a generic description of the oceanic, nearshore, and coastal environments within the OTEC resource area. The OTEC resource area (Figures 3-1a and 3-1b) includes all tropical-subtropical regions of the world that possess sufficient thermal gradients for OTEC operation. Several candidate regions within the OTEC resource area are likely to be used for commercial OTEC power production by the year 2000. These candidate regions encompass the eastern Gulf of Mexico, various open-ocean plantship areas, and several island communities, including Puerto Rico, the U.S. Virgin Islands, the Hawaiian Islands, Guam, and the Pacific Trust Territories. Detailed maps of these candidate OTEC areas are presented in Appendix C.

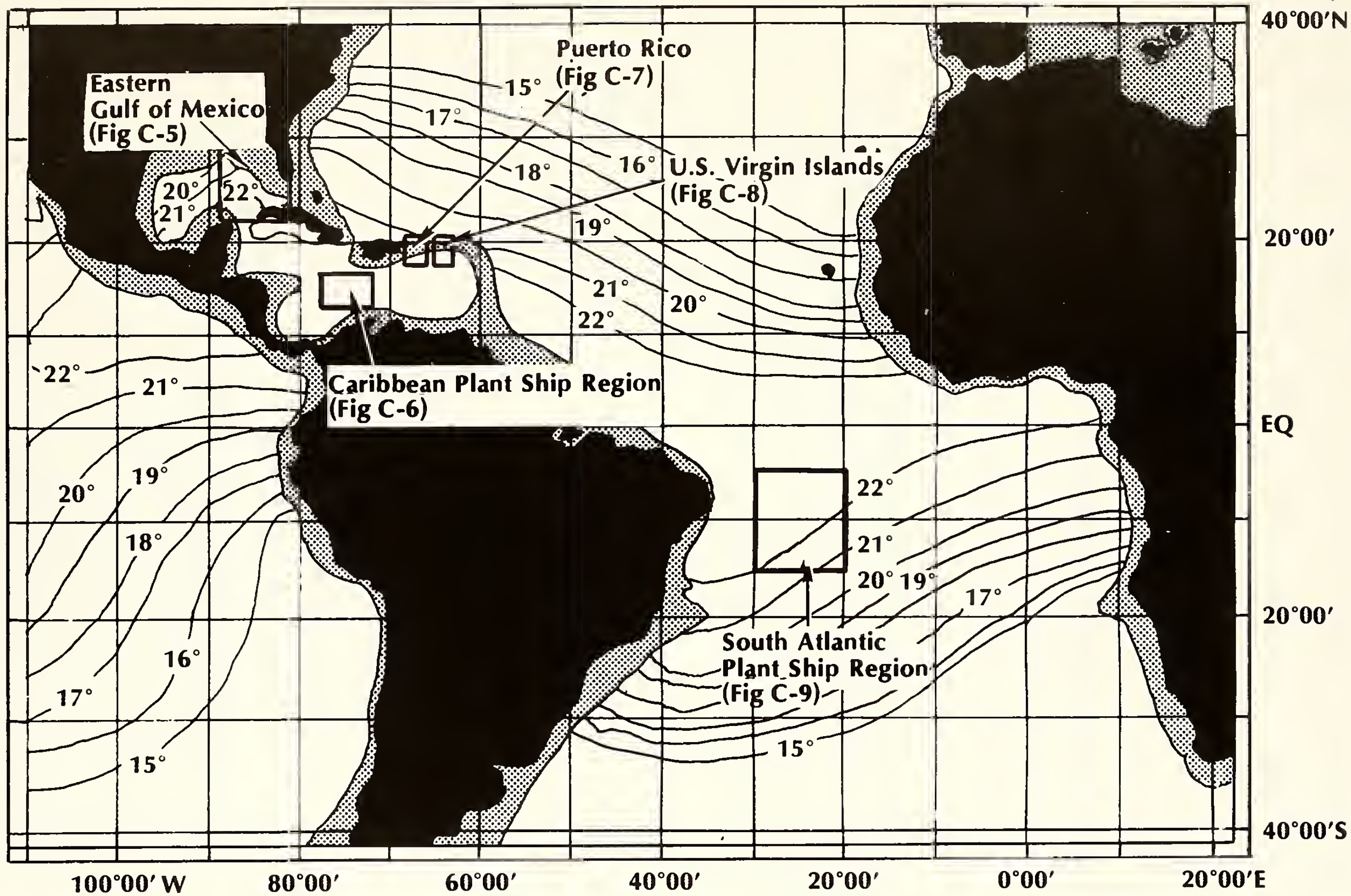
This chapter is not intended to be a site-specific description. The parameters which are considered: (1) describe the salient environmental and economic features under which single or multiple OTEC deployments are projected to operate, and (2) facilitate the assessment of impacts. Data from numerous sources have been pooled to prepare this environmental characterization. Section 3.1 presents the typical atmospheric conditions in candidate OTEC areas. Section 3.2 generically describes marine environmental



< 500 m deep

*Contours indicate temperature differential (°C) between surface and 1000 m depth
**Detailed charts of potential siting regions are presented in Appendix C.

Figure 3-1a. The OTEC Thermal Resource Area (Pacific)
Source: DOE, 1978a



*Contours indicate temperature differential (°C) between surface and 1000 m depth
**Detailed charts of potential siting regions are presented in Appendix C.

Figure 3-1b. The OTEC Thermal Resource Resource Area (Atlantic)
Source: DOE, 1978a

conditions within the OTEC resource area by summarizing differences between nearshore and offshore environments. Coastal environments are discussed, and existing-use areas identified, in Section 3.3. Terrestrial environments at candidate land-based OTEC sites in island communities are generically described in Section 3.4.

3.1 THE ATMOSPHERE

3.1.1 Data Requirements for Impact Assessment

Descriptions of typical weather patterns, carbon dioxide sinks and sources, and climates within the OTEC resource area are important for assessing the atmospheric effects of commercial OTEC development. The occurrence of extreme meteorological conditions must be considered during site selection because OTEC plants should be designed to operate and survive in both typical and extreme wind, wave, and current conditions.

In addition to considering the effect of atmospheric conditions on OTEC deployment and siting, the effect of OTEC operation on the atmosphere must also be considered. OTEC plants will bring cold, carbon-dioxide rich, deep water to the surface, releasing carbon dioxide to the atmosphere and causing a decrease in sea-surface temperatures. Increased atmospheric carbon dioxide concentrations may influence global temperatures and climate patterns by disrupting the natural equilibrium between incoming and outgoing radiation, potentially causing average global temperatures to increase. The near-surface discharge of cold water pumped from great depths and the extraction of heat from surface waters could alter sea-surface temperatures, which strongly influence weather and climatic patterns.

3.1.2 Description

3.1.2.1 Climate - Climates within the OTEC resource area are influenced by large-scale atmospheric patterns, sea-surface temperatures of surrounding ocean waters, and the proximity of landmasses. Two basic types of climates occur within the OTEC resource area: maritime and oceanic. Maritime climate

is strongly influenced by both continental landmasses and oceanic waters and is characterized by larger, more rapid temperature changes than the oceanic climate. The oceanic climate is influenced to a greater degree by the ocean's sea-surface temperature than the maritime climate, and is therefore characterized by smaller, more gradual temperature changes.

Local maritime climates within the OTEC resource area are often influenced by an onshore-offshore wind cycle caused by the differential heating of landmasses and ocean waters. In areas with steep coastal mountain ranges, such as the Hawaiian Islands, this wind cycle causes moisture-laden marine air to cool as it rises against the coastal mountains, losing its moisture as precipitation. Consequently, the windward sides of such islands typically experience heavier rainfall than the leeward sides (University of Hawaii, 1973). Strong nearshore upwelling zones can modify this pattern. Surface layers of cold upwelled water can cause the moisture-laden marine air to precipitate its moisture before reaching land, resulting in heavy fogs and arid desert-like coastlines.

3.1.2.2 Tropical Storms and Hurricanes - The OTEC thermal resource area is within the tropical trade wind belt. Large-scale atmospheric disturbances in this area are known as tropical cyclones and are classified according to windspeed: tropical depressions are cyclones with maximum sustained windspeeds below 63 kilometers per hour (kph); tropical storms have windspeeds between 63 kph and 119 kph; hurricanes are cyclones with windspeeds exceeding 119 kph. Figure 3-2 illustrates the monthly and annual average storm occurrence for the major ocean basins. Tropical cyclones commonly occur from May to November in the northern half of the trade wind belt, and from December to June in the southern half (Crutcher and Quayle, 1974). Tropical cyclones are most frequent in the eastern and western North Pacific. In the western North Pacific and the North Atlantic, cyclones reach hurricane intensity more often than in the eastern North Pacific (Figures 3-3a and 3-3b). Hurricanes frequently occur in the Gulf of Mexico and Caribbean Sea. No hurricanes have been observed in the South Atlantic.

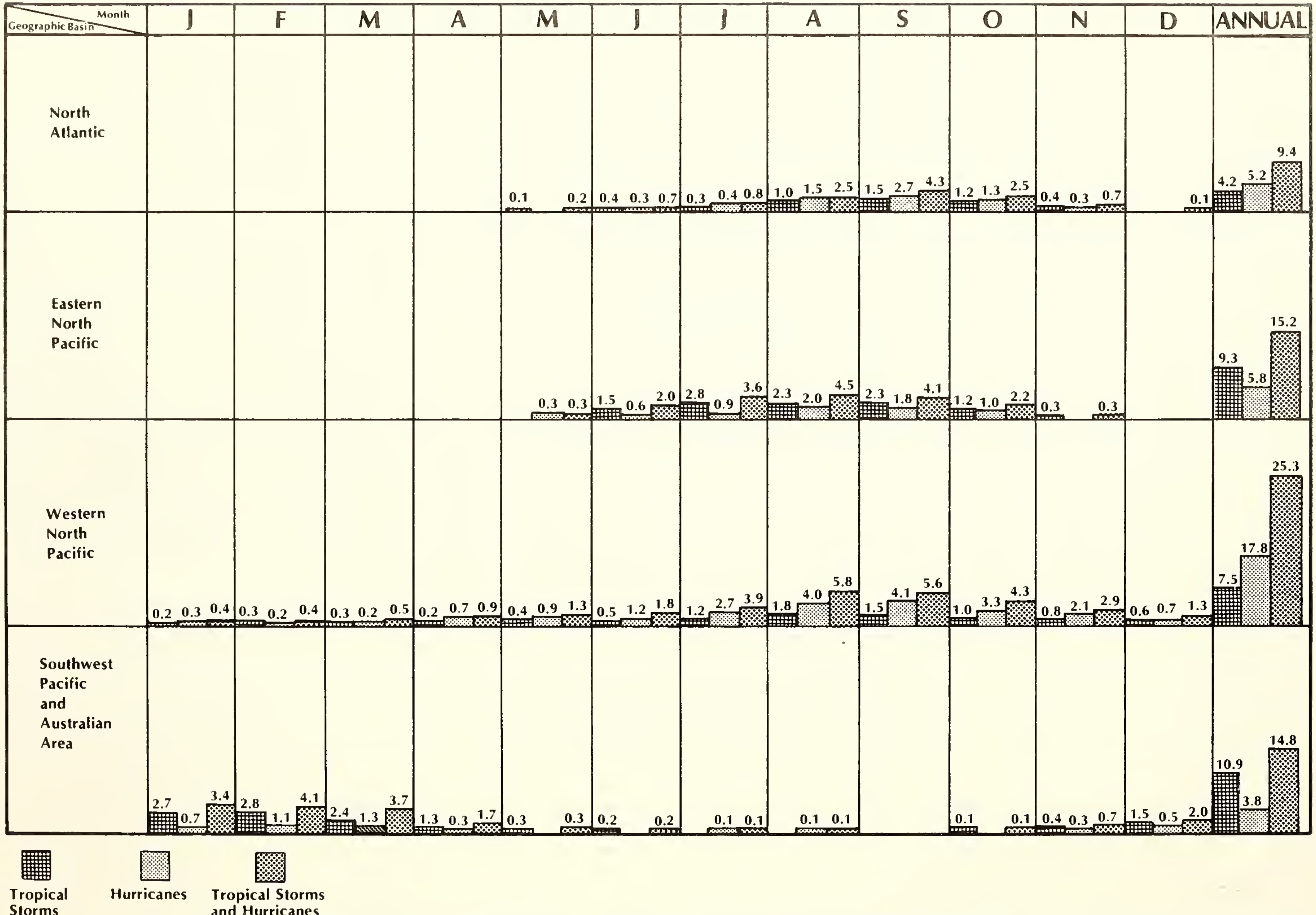
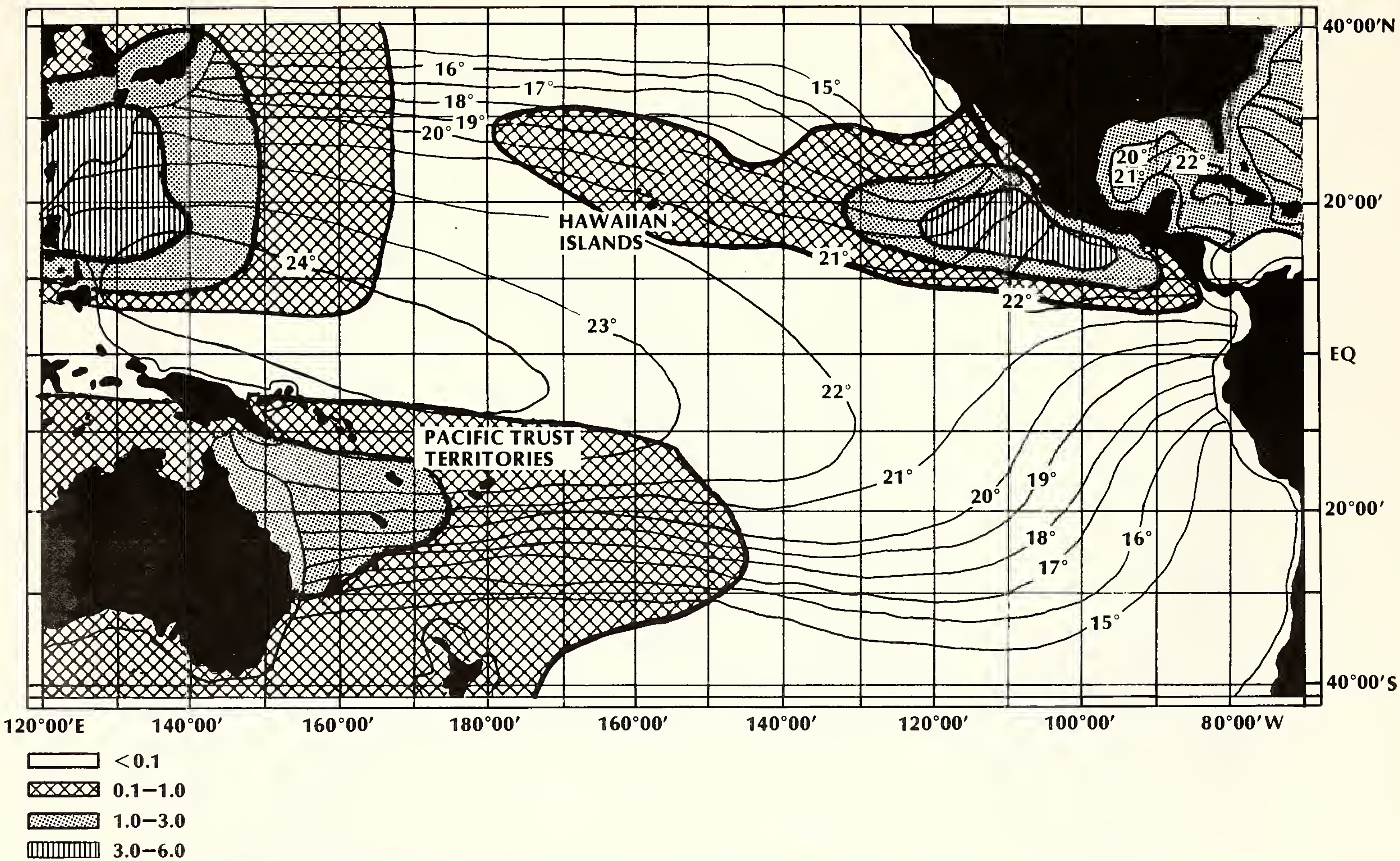
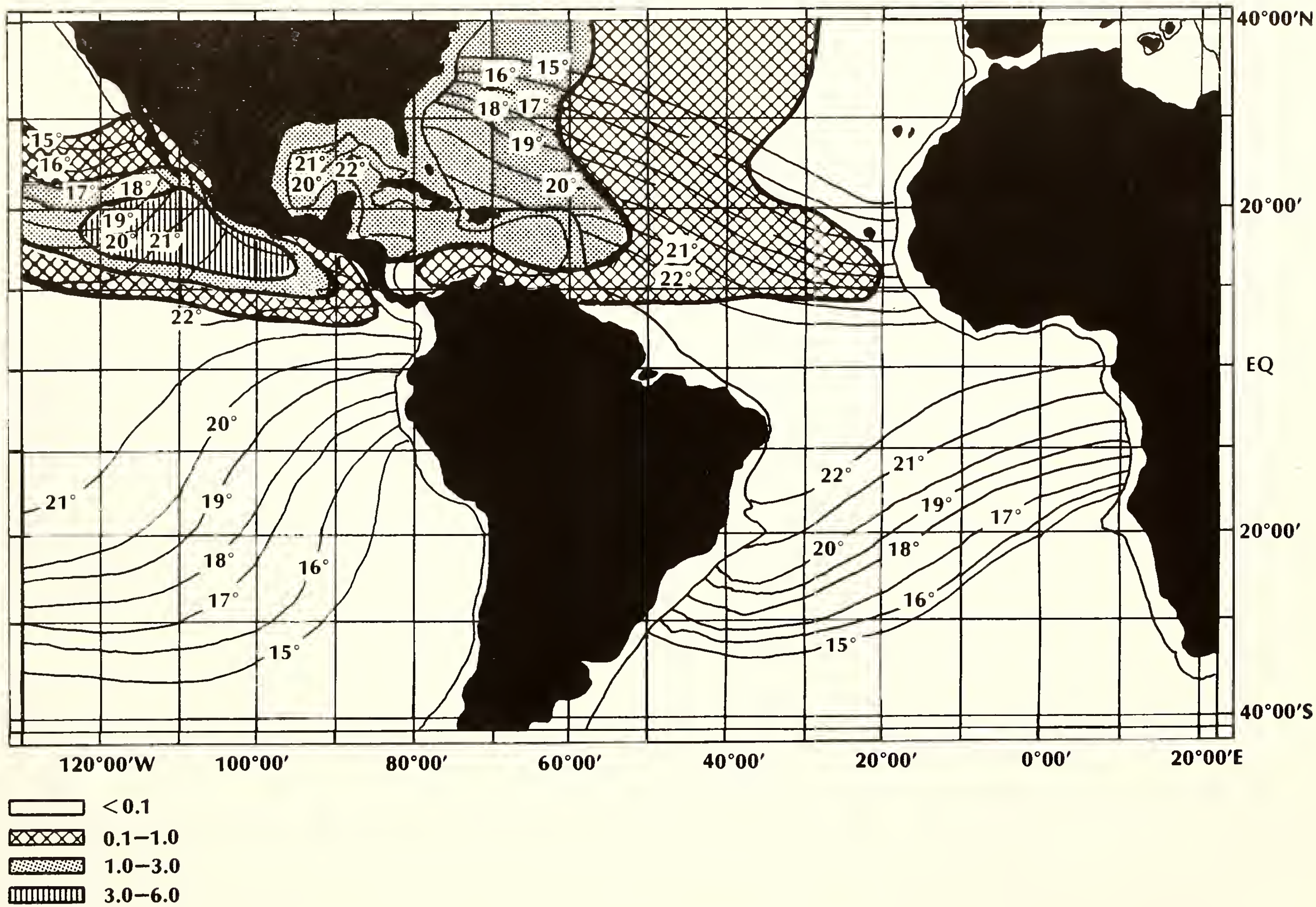


Figure 3-2. Monthly and Annual Average Storms for Major Ocean Basins (Percent Frequency of Occurrence)
Source: Crutcher and Quayle, 1974



*Contours indicate temperature differential (°C) between surface and 1000 m depth

Figure 3-3a. Annual Frequency of Tropical Cyclones (Pacific)
Source: Crutcher and Quayle, 1974



*Contours indicate temperature differential (°C) between surface and 1000 m depth

Figure 3-3b. Annual Frequency of Tropical Cyclones (Atlantic)
Source: Crutcher and Quayle, 1974

3.1.2.3 Carbon Dioxide - The atmosphere and the world oceans are the two major reservoirs of carbon dioxide. The oceanic reservoir is estimated to contain 3.5×10^{16} kg of carbon dioxide in various chemical forms, whereas the atmosphere contains about 6.4×10^{14} kg (Brewer, 1978). The global atmospheric carbon dioxide concentration is steadily increasing (Figure 3-4). Carbon dioxide levels prior the industrial revolution were about 270 to 290 parts per million (ppm) by volume; present-day levels are approximately 330 to 335 ppm (Keeling and Bacastow, 1977). The combustion of fossil fuels is the major source of atmospheric carbon dioxide increases. Additional sources are cement production, which involves the removal of carbon dioxide from limestone, and massive reductions in terrestrial biomass from the clearing of forests, burning of firewood, and large-scale agricultural practices (Brewer, 1978). Although OTEC power production will be a source of atmospheric carbon dioxide increase, the increase would be significantly less than that which would occur with equivalent fossil-fueled power production.

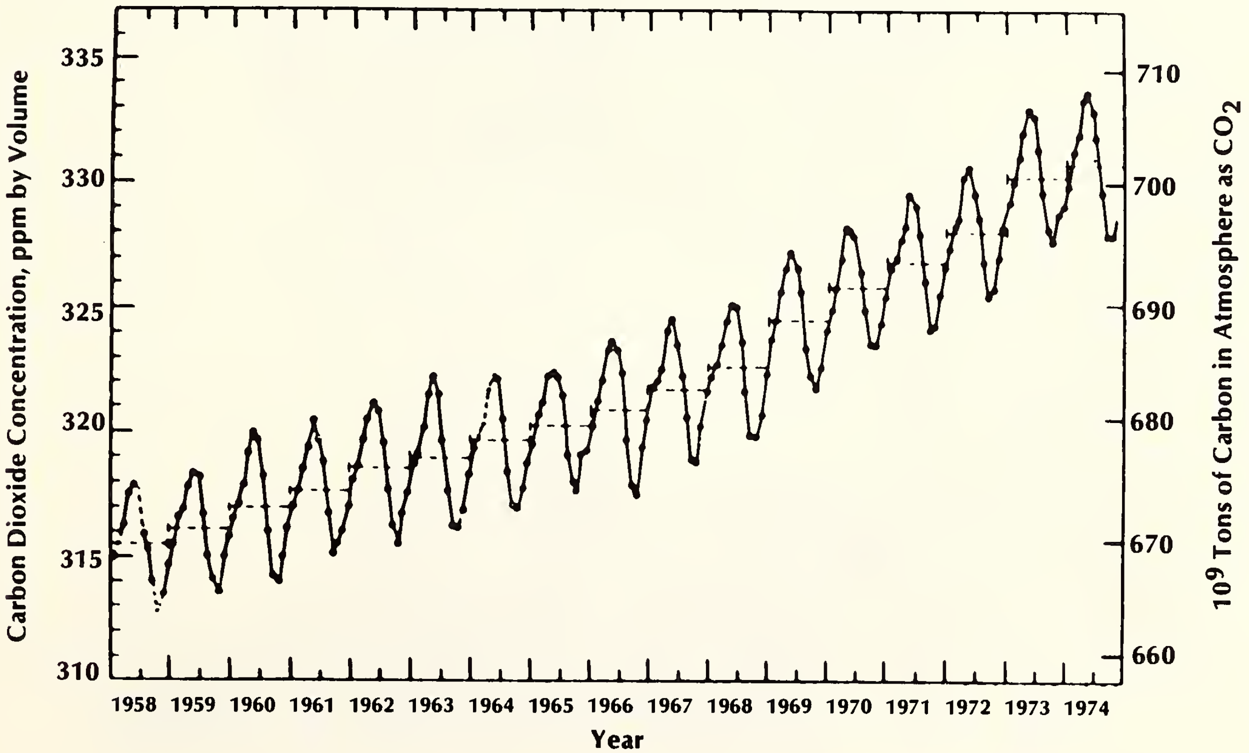


Figure 3-4. Recent Atmospheric Carbon Dioxide Increases
Source: Brewer, 1978

The influence of vegetation on atmospheric carbon dioxide concentration is evident in seasonal cycles of carbon dioxide concentrations (Figure 3-4). This annual variation in concentration, averaging 6 to 7 ppm in the tropics, is attributed to the uptake of carbon dioxide by green plants during summer growth periods and release of carbon dioxide through decomposition and respiration during winter months (Brewer, 1978). Large-scale destruction of forests in the tropical-subtropical regions has released large amounts of carbon dioxide and significantly reduced the land's capacity to absorb atmospheric carbon dioxide.

The deep ocean is the major sink for carbon dioxide. Since carbon dioxide is less soluble in warm water than cold water, warm ocean waters contain less carbon dioxide than colder ocean waters. In most tropical-subtropical waters, carbon dioxide-rich water is sufficiently warmed to release carbon dioxide to the atmosphere (Figures 3-5a and 3-5b); however, many regions within the OTEC resource area are sinks for atmospheric carbon dioxide.

Although the increase in atmospheric carbon dioxide can be readily measured, the oceanic carbon dioxide increase is more difficult to detect. Presently, the detection limit for carbon dioxide in seawater is 50 ppm, which approximates the total atmospheric increase of carbon dioxide since the beginning of the industrial revolution. Consequently, it is difficult to estimate the impact of industrial carbon dioxide releases on oceanic carbon dioxide concentrations and to predict the capacity of the oceans to assimilate further increases in atmospheric carbon dioxide.

3.2 THE MARINE ENVIRONMENT

3.2.1 Data Requirements for Impact Assessment

Physical, chemical, and biological parameters are required to evaluate the environmental consequences of commercial OTEC development. Geological

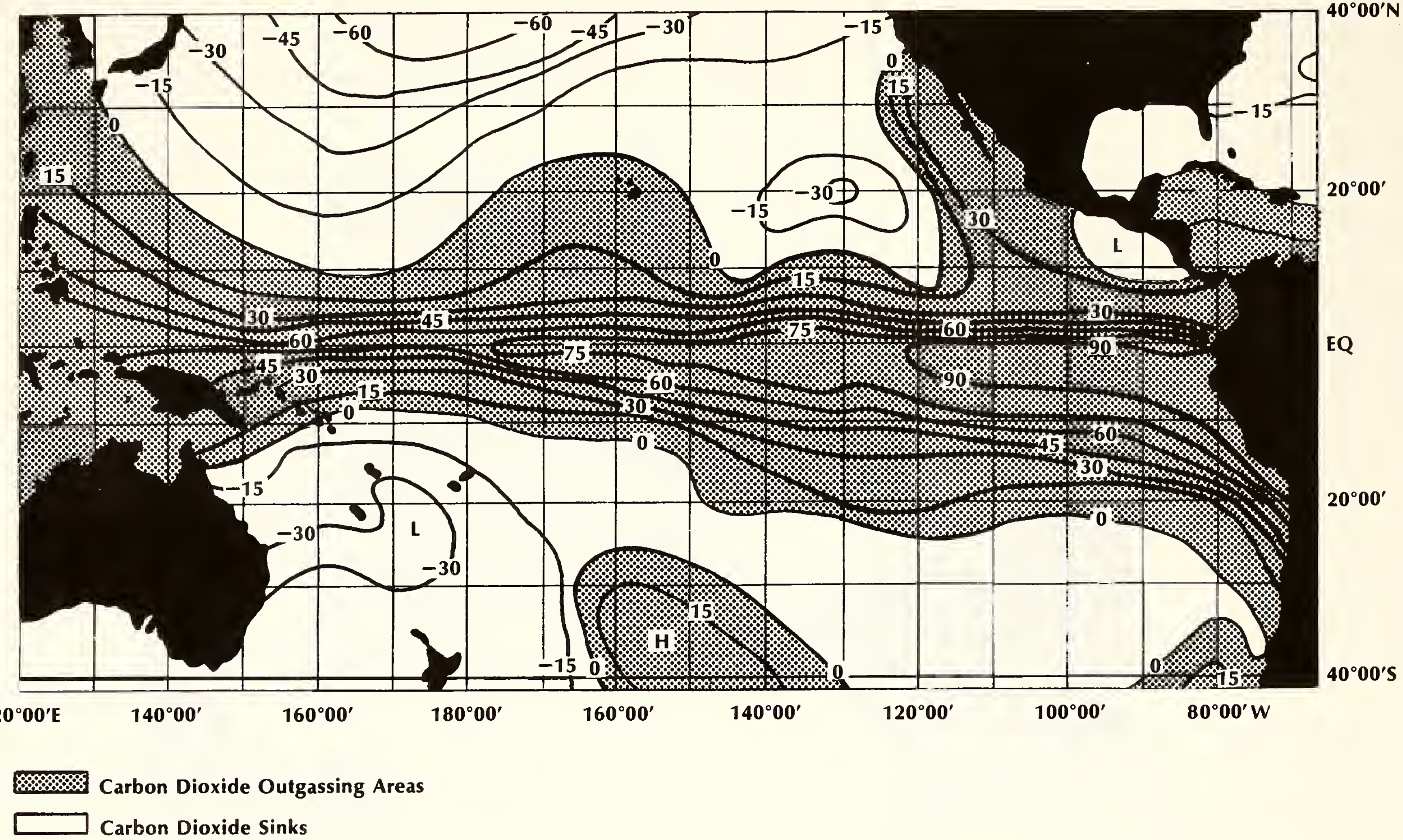


Figure 3-5a. Carbon Dioxide Outgassing Regions in the OTEC Resource Area (Pacific). Contours are in carbon dioxide concentrations (parts per million) from saturation. Source: Adapted from Brewer, 1978.

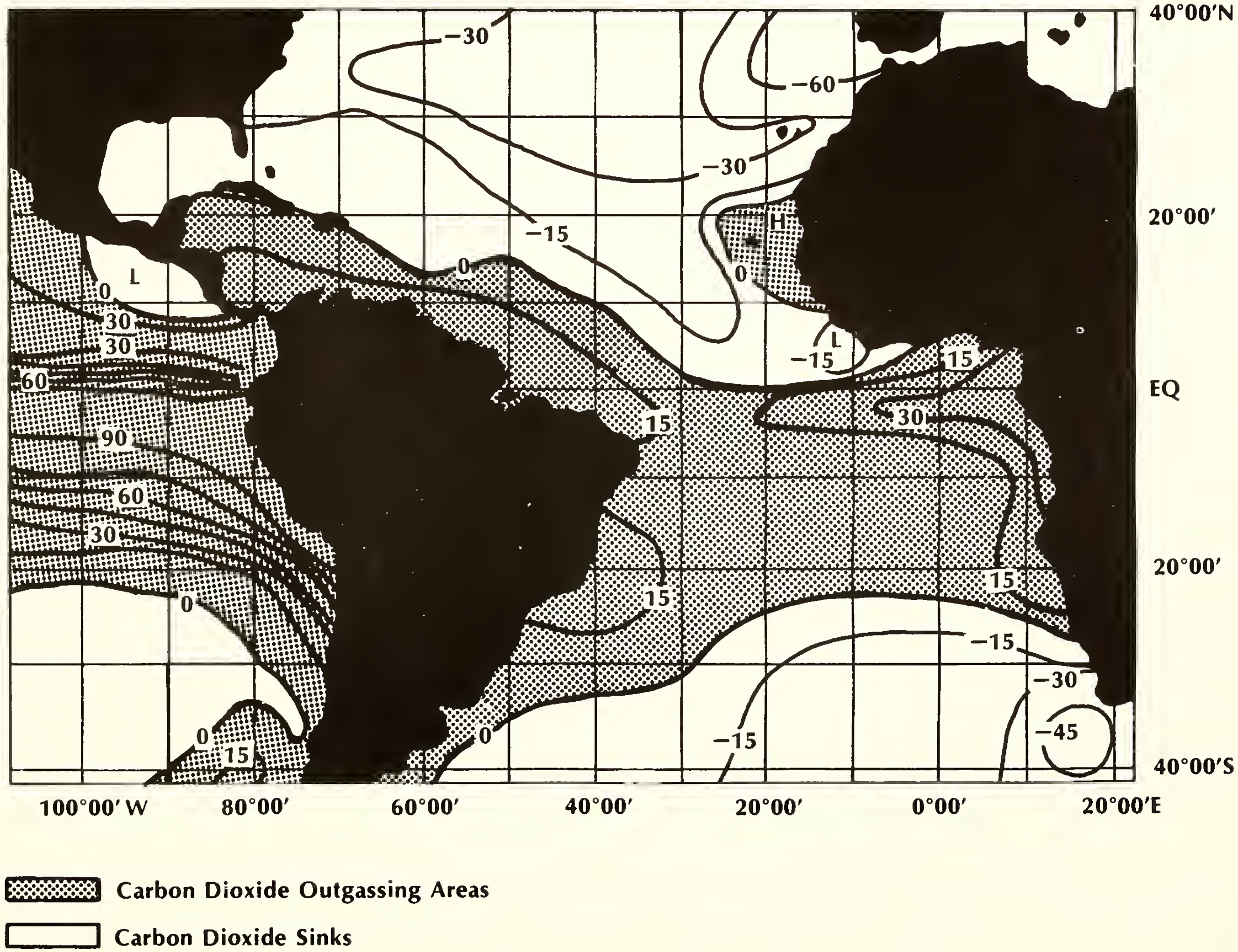


Figure 3-5b. Carbon Dioxide Outgassing Regions in the OTEC Resource Area (Atlantic). Contours are in carbon dioxide concentrations (parts per million) from saturation. Source: Adapted from Brewer, 1978.

parameters are important for siting and design of commercial OTEC plants, but generally not for environmental impact evaluation. Therefore, the variability of geological conditions within the OTEC resource area is not further considered here.

Physical characteristics that are essential for assessing the effects of commercial OTEC development on the marine environment include thermal profiles, mixed-layer depths, circulation patterns, and photic-zone depths. The thermal profile is fundamentally critical to OTEC operation; OTEC siting areas should have an annual temperature difference of approximately 20^{o}C between surface and deep-ocean waters. The mixed-layer depth provides information on the structure of the upper water column. The mixed-layer depth must be deep enough to ensure that the warm-water resource is continually available at the intake depth. The mixed-layer depth is also a consideration in selecting the discharge depth because the depth of discharge, in relation to the mixed-layer depth, influences the effects from recirculation of OTEC discharged waters by downstream plants, sea-surface temperature alterations, and nutrient enrichment of the photic zone. The photic-zone depth is used to estimate the increased biological productivity that may result from nutrient redistribution.

Circulation patterns within the OTEC resource area are important because of their effect on thermal resource renewal and discharge plume dynamics. Circulation patterns will both replenish the withdrawn water and disperse the discharged water used by OTEC plants, thereby maintaining the thermal resource. Subsurface currents and internal waves will apply stress to the cold-water pipe; winds, waves, and tidal currents will supply forces that act on the platform.

Chemical characteristics relevant to OTEC environmental assessments include nutrient and dissolved oxygen profiles from the surface to the cold-water intake depth. These values are necessary for assessing the effect of water mass redistribution. Table 3-1 summarizes the available physical and chemical data for several major regions of the OTEC resource area. Other

TABLE 3-1
PHYSICAL AND CHEMICAL CHARACTERISTICS OF OTEC RESOURCE AREAS

Parameter		ISLANDS (Hawaii, Puerto Rico, Virgin Islands, Pacific Trust Territories, Guam)	OCEAN (Atlantic and Pacific)	Gulf of Mexico
Mixed-Layer Depth (m)		40-100 [a,b,c]	10-80 [d,e]	60-120 [f]
Photic-Zone Depth (m)		120-140 [g,h]	120-140 [g,h]	50-125 [i]
Nitrate	0-50 m	0.05-0.7 [j,k,l]	0.04-0.2 [m,n]	0.17-1.0 [i,o]
(mg-atom m^{-3})	125 m	0.6-0.7 [k,l]	0.2-0.5 [j,o]	7 [o]
	900 m	23-45 [j,k,p]	29-34 [q]	30 [o]
Phosphate	0-50 m	0.2-0.4 [j,l,r]	0.1-0.26 [n,q,s]	0.07-0.5 [i,t]
(mg-atom m^{-3})	125 m	0.2-0.5 [j,l,r]	0.3-0.6 [q]	0.5 [t]
	900 m	2.0-3.0 [j,r]	1.4-2.0 [m,q]	1.9 [t]
Silicate	0.50 m	1.0-4.8 [o,j]	0.0-2.4 [n,q]	0.5-4.4 [i,o]
(mg-atom m^{-3})	125 m	1.0-3.7 [o,j]	5-25 [q]	2 [o]
	900 m	25-86 [o,j]	20-150 [q]	25 [o]
Dissolved	0-50 m	4.8-7.5 [j,l,u]	4.3-4.8 [m,n,u]	4.8 [v]
Oxygen	125 m	3.0-7.4 [j,l,u]	3.0 [n,u]	3.6 [o]
(ml $liter^{-1}$)	900 m	1.0-3.4 [j,u,w]	3.4 [u]	3.9 [o]

(a) ODSI, 1977a
(b) ODSI, 1977b
(c) ODSI, 1979a
(d) ODSI, 1979b
(e) Molinari and Chew, 1979
(f) ODSI, 1977c
(g) Hargraves et al., 1970
(h) Gundersen et al., 1976
(i) EL-Sayed et al., 1972
(j) Lawrence Berkeley Laboratory, 1980
(k) Atwood et al., 1976
(l) Gunderson and Palmer, 1972
(m) Arsen'ev et al., 1973
(n) Love, 1971
(o) Cummings et al., 1979
(p) Gundersen et al., 1972
(q) Sverdrup et al., 1942
(r) Halminski, 1975
(s) Schulenberger, 1978
(t) Churgin and Halminski, 1974
(u) Gross, 1977
(v) Michel and Foyo, 1976
(w) Gordon, 1970

important chemical parameters include ambient levels of trace constituents and organohalogen compounds in the water column and in tissues of resident organisms.

Assessing the environmental consequences of commercial OTEC development requires a general description of the biological community inhabiting the OTEC resource area. Descriptions of the vertical and geographical distribution of phytoplankton and zooplankton populations are necessary (Table 3-2), along with the biological productivity and commercial value of fisheries in various areas. Special attention must be given to the distribution and migration of threatened and endangered species (Table 3-3), and species of commercial importance, such as tuna, billfish, dolphin, and clupeid fish.

3.2.2 Description

Physical, chemical, and biological properties in marine waters within the OTEC resource area are not homogeneous but do exhibit some similarities from place to place, especially in terms of horizontal and vertical trends. One of the most marked horizontal trends is the transition from nearshore to offshore marine environments. The nearshore environment is the region extending seaward from the shore to approximately the edge of the continental shelf. This region is influenced by continental conditions, such as terrestrial runoff, tidal mixing, and coastal upwelling. The nearshore region is highly productive and the location of most of the major world fisheries. The offshore environment is minimally influenced by continental conditions. In the OTEC resource area, the offshore environment is characterized by lower productivity and fewer commercial fisheries than nearshore areas.

Nearshore areas generally support a greater density of marine life than offshore areas because increased mixing, freshwater input, and coastal upwelling continually restore essential nutrients to sunlit surface waters, where primary production occurs. In addition, the shallow water in the nearshore zone allows nutrients regenerated by the benthic community to be mixed throughout the photic zone. Coastal and upwelling food chains are

TABLE 3-2
CHARACTERISTICS OF THE PLANKTON IN THE OTEC RESOURCE AREA

Parameter	Depth	ISLANDS (Hawaii, Puerto Rico, Virgin Islands)	OCEANIC Atlantic and Pacific (Tropical)	Gulf of Mexico
Primary Productivity mg C m^{-2} day	0-130 m	30-280 [a,b]	50-375 [c,d,e]	60-100 [f]
Chlorophyll-a mg m^{-3}	0-50 m	0.03-0.25 [a,d,g,h,i]	0.03-0.12 [a,d,g,h,j,k,l,m]	0.05-0.20 [n]
	80-130 m	0.12-0.39 [a,d,g,h,i]	0.1-0.3 [j,k,l,m]	0.05-0.40 [n]
Microzooplankton mg C m^{-3}	0-200 m	0.8 [d]	1.0 [o]	No Data
	200-350 m	No Data	0.1 [p]	No Data
	350-1000 m	No Data	0.01 [q]	No Data
Macrozooplankton Night/Day Biomass Ratio	0-150 m	1.25-1.65 [c]	1.1-1.8 [o,r,s]	2.3 [t]
Macrozooplankton Biomass mg C m^{-3}	0-150 m	0.5-0.8 [u,v,w,x]	0.1-3.0 [o,p,r,s]	0.1-6.0 [t,y]
	150-350 m	0.2 [v]	0.1-0.7 [s,z]	No Data
	350-1000 m	No Data	0.4 [o]	0.25 [v]

(a) Gilmartin and Revelante, 1974
(b) Beers et al., 1968
(c) Koblentz-Mishke et al., 1970
(d) Gunderson et al, 1976
(e) Mahnken, 1969
(f) Jones et al., 1973
(g) Johnson and Horne, 1979
(h) Bathen, 1977
(i) Hargraves et al., 1970
(j) Scripps Institute of Oceanography, 1969
(k) Venrick et al., 1973
(l) Eppley et al., 1973
(m) Schulenberger, 1978
(n) El-Sayed et al., 1972
(o) Hirota, 1977
(p) Beers and Stewart, 1969
(q) Beers, 1978
(r) Vinogradov and Rudyakov, 1973
(s) Youngbluth, 1975
(t) Howey, 1976
(u) Nakamura, 1955
(v) King and Hida, 1954
(w) King and Hida, 1957
(x) Shomura and Nakamura, 1969
(y) Bogdanov et al., 1969
(z) Vinogradov, 1961

TABLE 3-3
THREATENED AND ENDANGERED SPECIES OF THE OTEC RESOURCE AREA (MARINE)
Source: Sands, 1980.

Scientific Name	Common Name	Status	Distribution
		Marine Mammals	
Balaenoptera musculus	Blue whale	E*	Oceanic, Pacific, Atlantic
Balaenoptera borealis	Sei whale	E	Oceanic, Pacific, Atlantic
Balaenoptera physalus	Finback whale	E	Oceanic, Southern Hemisphere
Eschrichtius gibbosus	Grey whale	E	Oceanic, off western North America
Eubalaena glacialis	Right whale	E	Oceanic, Pacific, Atlantic
Megaptera novaeangliae	Humpback whale	E	Oceanic, Caribbean, North Pacific, Atlantic
Physeter catodon	Sperm whale	E	Oceanic, Caribbean, Pacific, Atlantic
Dugong dugong	Dugong	E	Micronesia, Western Carolines, TTPI**
Trichechus manatus	Caribbean manatee	E	Off Florida, Caribbean
Monachus schauinslandi	Hawaiian monk seal	E	Northwest Hawaiian Islands
Monachus tropicalis	Caribbean monk seal	E	Caribbean (extinct?)
		Sea Turtles	
Chelonia mydas	Green sea turtle	T*** E	Hawaii **Florida, Pacific coast of Mexico**
Eretmochelys imbricata	Hawksbill	E	Micronesia, TTPI, **Gulf of Mexico**
Dermochelys coriacea	Leatherback	E	Micronesia, TTPI, Caribbean, **Gulf of Mexico**
Lepidochelys kempii	Kemp's ridley	E	Caribbean, **Gulf of Mexico**
Lepidochelys olivacea	Olive ridley	T E	Tropical circumglobal, **Pacific coast of Mexico**
Caretta caretta	Loggerhead	T	Tropical circumglobal
		Birds	
Pelecanus occidentalis	Brown pelican	E	Caribbean, U.S. west coast, Gulf coasts
Puffinus puffinus newelli	Newel's Manx shearwater	T	Hawaiian Islands
Pterodroma phaeopygia sandwichensis	Hawaiian dark-rumped petrel	E	Hawaiian Islands

*Endangered
**Trust Territories of the Pacific Islands
***Threatened

characteristically shorter (1 to 3 trophic levels) and have higher efficiencies (15-20% between trophic levels) than oceanic food chains (5 trophic levels, 10% efficiency; Table 3-4). The total catch of pelagic resources from the nearshore zone is an order of magnitude greater than from the open sea, and the catch per unit area is almost 150 times greater on the shelf than it is at sea (Moiseev, 1971). Furthermore, coral reefs on the continental shelf are among the most highly productive communities, in terms of biomass and species diversity (Pequegnat, 1964).

Nearshore environments contain a higher proportion of ecologically-sensitive areas than offshore environments. The nearshore is restricted in size, but serves as a nursery ground for many species of fish and benthic invertebrates. In addition, the nearshore region is also used by many marine reptiles and marine mammals for breeding and nursery grounds.

Characteristics of the nearshore and offshore marine environments in the OTEC resource area are described in the following subsections.

3.2.2.1 Nearshore Environment - The nearshore marine environment is generally defined as the region between the shoreline and continental shelf break, encompassing the intertidal, subtidal, inner-continental shelf, and outer-continental shelf regions. Circulation patterns of nearshore areas are variable, and are primarily driven by winds and tides, with some influence from large-scale oceanic currents. Strong tidal currents, seasonably variable winds, and irregularities in circulation patterns cause increased mixing of surface and bottom waters in nearshore areas.

Physical processes along the edge of continental margins may cause upward mixing of nutrient-rich deep waters for some areas with narrow continental shelves (e.g., west coast of North America, most island systems). This upwelling process is caused by: (1) winds blowing parallel to shore, with subsequent offshore Ekman transport of waters, or (2) current divergences toward the surface caused by continental features (e.g., escarpments, headlands, submarine canyons). Upwelling of nutrient-rich deep waters into

TABLE 3-4 TYPICAL NEARSHORE (COASTAL, UPWELLING) AND OFFSHORE (OCEANIC) FOOD CHAINS
Source: Adapted from Ryther, 1969

Oceanic Food Chain (10% Efficiency)

Nannoplankton (small flagellates) → Microzooplankton (herbivorous zooplankton and protozoa) → Macrozooplankton (carnivorous zooplankton) → Megazooplankton (chaetognaths, euphausiids) → Planktivores (mesopelagic fish) → Piscivores (tuna, squid, and saury) → Human Consumption

Coastal Food Chain (15% Efficiency)

Phytoplankton (diatoms, dinoflagellates) → Macrozooplankton (herbivorous zooplankton) → Planktivores (clupeid fish) → Piscivores (tuna) → Human Consumption

Upwelling Food Chain (20% Efficiency)

Macrophytoplankton (large, chain-forming species) → Planktivores (clupeid fish)
Macrophytoplankton (large, chain-forming species) → Megazooplankton (euphausiids)
Planktivores (clupeid fish) → Human Consumption
Planktivores (clupeid fish) → Piscivores (tuna)
Megazooplankton (euphausiids) → Piscivores (tuna)
Piscivores (tuna) → Human Consumption

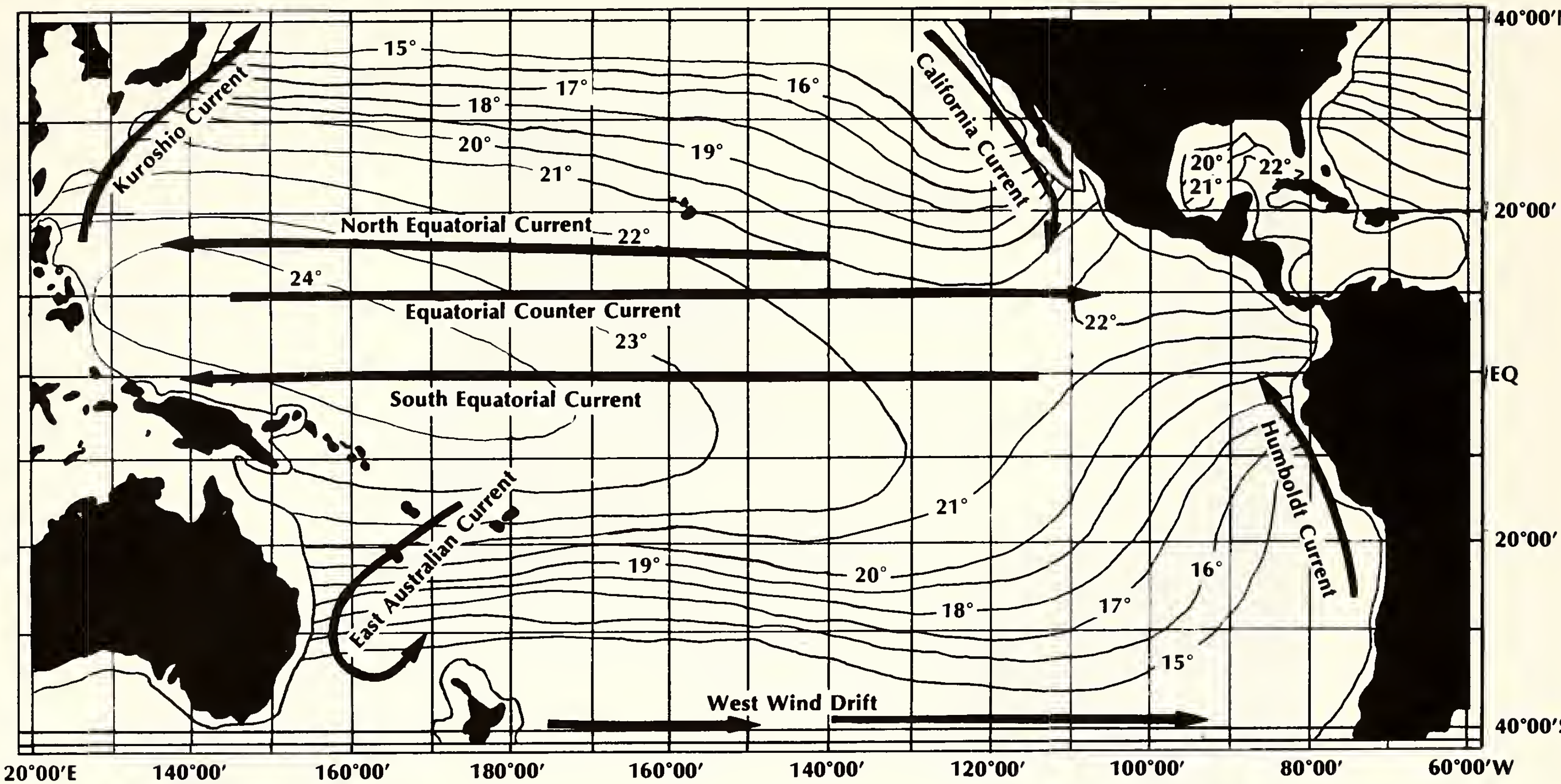
surface layers of the water column results in higher productivity. The upwelled nutrient-rich waters that result from mixing over the continental shelf may be transported offshore by prevailing current systems.

Two types of nearshore environments are present in the OTEC resource area. The Gulf of Mexico has a wide shallow shelf strongly influenced by

coastal processes. Wind-induced turbulence, freshwater input, tidal mixing and partial isolation from the major ocean basins by the wide continental shelf significantly affects the nearshore environment in the Gulf of Mexico, causing high seasonal variability of physical, chemical, and biological properties. Conversely, nearshore environments surrounding islands are characterized by a narrow continental shelf, greatly influenced by offshore (oceanic) processes, and experience less seasonal variation.

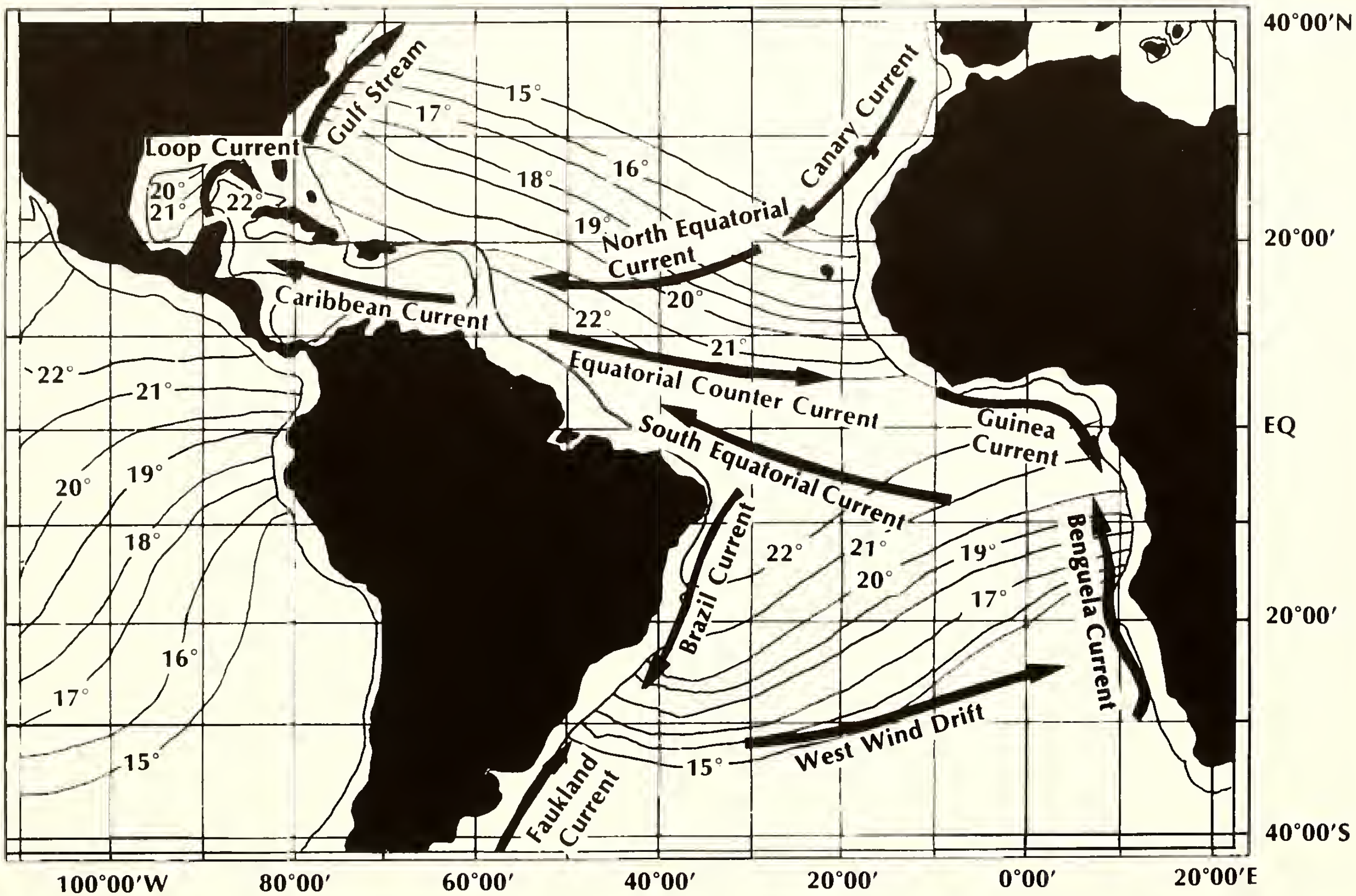
Differences in physical characteristics between island environments and the Gulf of Mexico become evident when comparing the organisms comprising the major fisheries in each region. Gulf of Mexico fisheries are primarily benthic (e.g., shrimp and demersal fishes), reflecting the enhanced benthic productivity resulting from mixing over the shallow continental shelf. Fisheries around islands are mainly composed of migratory offshore pelagic fish and reef fish, illustrating the influence of offshore and extreme nearshore processes in these areas.

3.2.2.2 Offshore Environment - The offshore marine environment is generally defined as the oceanic region seaward of the continental shelf break. Large-scale oceanic currents prevail over most of this region and tidal and continental influences are minimal. Major circulation patterns within the OTEC resource area are shown in Figures 3-6a and 3-6b. Vertical mixing occurs slowly, causing offshore waters to become vertically stratified. Vertical stratification reduces the recirculation of nutrients into the surface layer, resulting in typically low productivity (Table 3-5). The nutrient-poor offshore environment supports small phytoplankton cells resulting in long food chains (Ryther, 1969). The higher number of trophic levels and the less efficient transfer of energy between each level results in a smaller yield at the top of the food chain. Consequently, the open ocean, despite its high initial biomass, supports a low total fish yield. In areas such as the equatorial Pacific and the North Atlantic, where conditions allow the influx of nutrients to the surface layer, the open ocean is moderately productive.



*Contours indicate temperature differential (°C) between surface and 1000 m depth

Figure 3-6a. Major Circulation Patterns in the OTEC Resource Area (Pacific)
Source: Sands, 1980



*Contours indicate temperature differential (°C) between surface and 1000 m depth

Figure 3-6b. Major Circulation Patterns in the OTEC Resource Area (Atlantic)
Source: Sands, 1980

TABLE 3-5. DIVISION OF THE OCEANS INTO PROVINCES ACCORDING TO THEIR LEVEL OF PRIMARY PRODUCTIVITY
Source: Adapted from Ryther, 1969

Province	Percentage of Ocean	Area (km^2)	Mean Primary Productivity (g dry weight m^{-2} year $^{-1}$)	Total Primary Productivity (metric tons year $^{-1}$)	Percentage of Total Productivity	Number of Trophic Levels	Ecological Efficiency (percent)	Fish Production (metric tons)
Open Ocean	90.0	326×10^6	50	16.3×10^9	81.5	5	10	1.6
Nearshore Zone*	9.9	36×10^6	100	3.6×10^9	18.0	3	15	120
Upwelling Area	0.1	3.6×10^6	300	0.1×10^9	0.5	1-1/2	20	120

*Includes highly productive areas over the continental shelf.

Commercial offshore fisheries are mainly oriented around widely scattered, migratory species such as billfish and tuna. These fisheries are seasonal and operate on a low yield, high cash-return basis. Although open ocean commercial fisheries represent only about one percent of the entire world fish harvest (Rounsefell, 1973), their contribution to the world's fishing economy is substantial. In 1975-1976, offshore fisheries in the Eastern Tropical Pacific accounted for 30% of the total catch (Inter-American Tropical Tuna Commission, 1981). This represented a yearly total cash value in excess of $91 million.

The great depth of the water column in the offshore environment results in a variety of vertical habitats which, combined with a large number of trophic levels, creates a large diversity of organisms. Many of the species aggregate at great depths during the day, and migrate to the surface at night to feed in the more productive photic zone.

3.3 THE COASTAL ENVIRONMENT

3.3.1 Data Requirements For Impact Assessment

Commercial OTEC plants located within the coastal zone will affect both the marine and terrestrial environments. The coastal zone is heavily used by man and contains many existing-use areas which may be impacted by deployment and operation of OTEC plants. Information required to assess the magnitude of OTEC-related effects on coastal areas include:

- Location of ecologically-sensitive areas, such as seagrass beds, coral reefs, spawning grounds, and nursery areas.
- Location of existing-use areas, and any special regulations and permits associated with their use.
- Location of State and Federal jurisdictional limits, which determine the regulations which will affect OTEC operations.

3.3.2 Description

The coastal region extends seaward and inland from the shoreline and includes the nearshore marine and terrestrial environments. The coastal environment is heavily used by man for various commercial, recreational, cultural, and military purposes. High-conflict areas such as restricted military zones, marine sanctuaries, fishing grounds, and ecologically-sensitive areas will require site- and design-specific assessments to determine any possible impacts, whereas areas such as oil- and gas-lease areas and nonrestricted military-use zones may accommodate OTEC facilities without problems.

As a result of the increasingly high use of the coastal environment, the U.S. Congress passed the Coastal Zone Management Act of 1972 (amended in 1976 and 1978), which encouraged the preservation, protection, and development of the coastal zone. The Act and amendments established policies by which

coastal states could identify, preserve, restore, and develop areas of special environmental, cultural, or socioeconomic importance. Under the Act, areas of particular concern (APC) and special management areas (SMA) can be designated by each state. Any use or alteration of APC and SMA sites requires special state permits issued after an environmental impact statement on the proposed action has been prepared and approved.

OTEC plants may be sited in existing-use areas of the coastal region. Figures 3-7 through 3-10 identify the existing-use areas in the coastal environments most likely to be used for commercial OTEC development. Locations of APC's and SMA's are shown for all areas with the exception of the islands of Oahu and Hawaii, which presently designate their entire coastlines as SMA's.

Current U.S. jurisdiction applicable to commercial OTEC development is divided into two areas: (1) territorial sea and (2) the contiguous zone. The draft treaty being developed by the Third United Nations Conference on the Law of the Sea would allow 12-nautical mile territorial seas and 200-mile economic zones; however, this treaty has not been finalized by the United Nations and is not yet international law. Under current international and domestic law, the U.S. has a 12 nautical mile contiguous zone and a territorial sea of 3 nautical miles, except in areas which had wider territorial seas when they became part of the U.S. The present territorial sea and contiguous zone boundaries applicable to candidate U.S. OTEC development areas are listed in Table 3-6.

3.4 THE TERRESTRIAL ENVIRONMENT

3.4.1 Data Requirements for Impact Assessment

Land-based OTEC plant construction will disrupt the terrestrial environment in the vicinity of the site. In order to assess the impact of land based plant construction, a description of the existing flora and fauna found within the resource area should be presented, the accessibility of

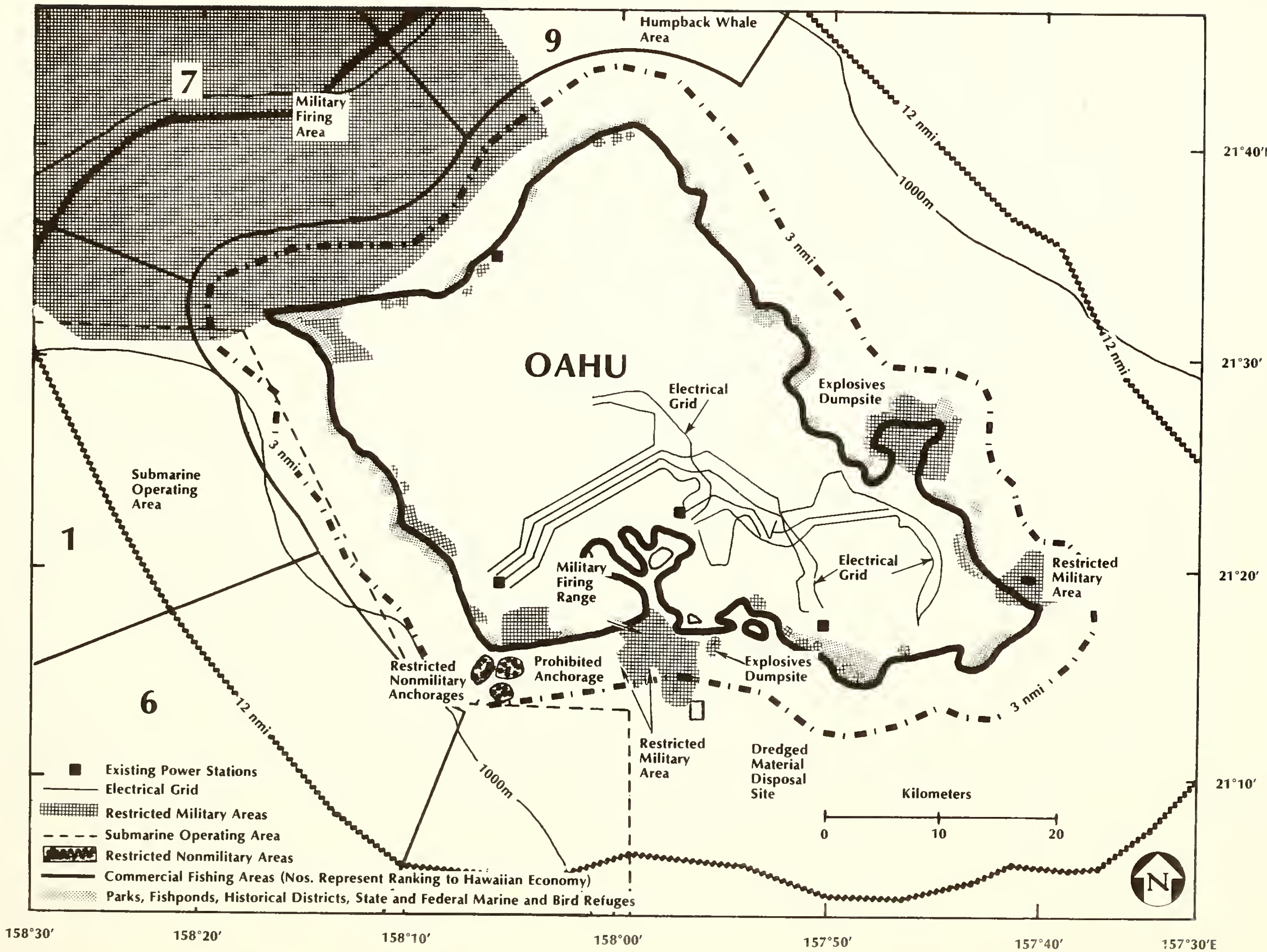


Figure 3-7. Existing-Use Areas in Oahu, Hawaii

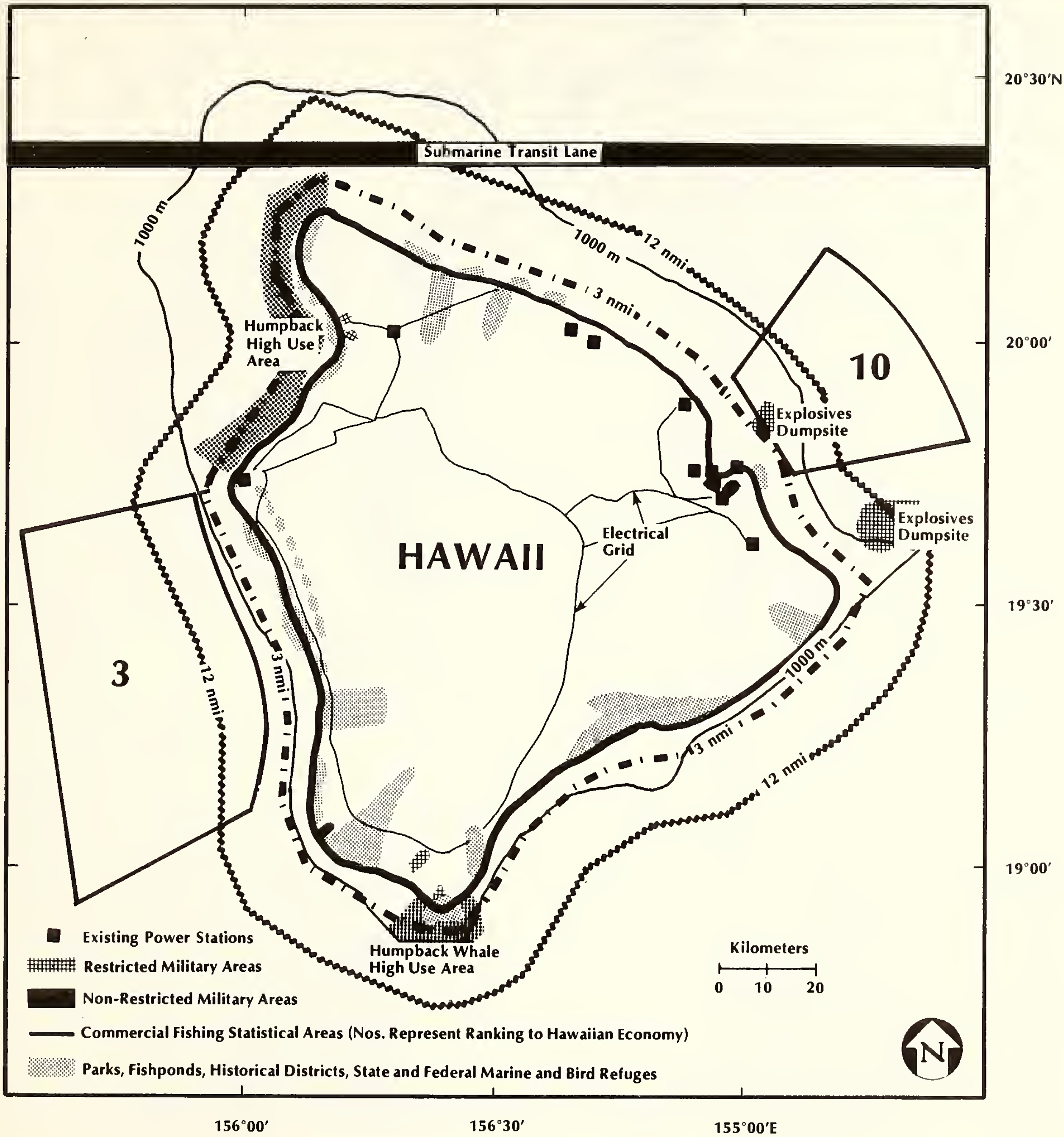


Figure 3-8. Existing-Use Areas in the Island of Hawaii

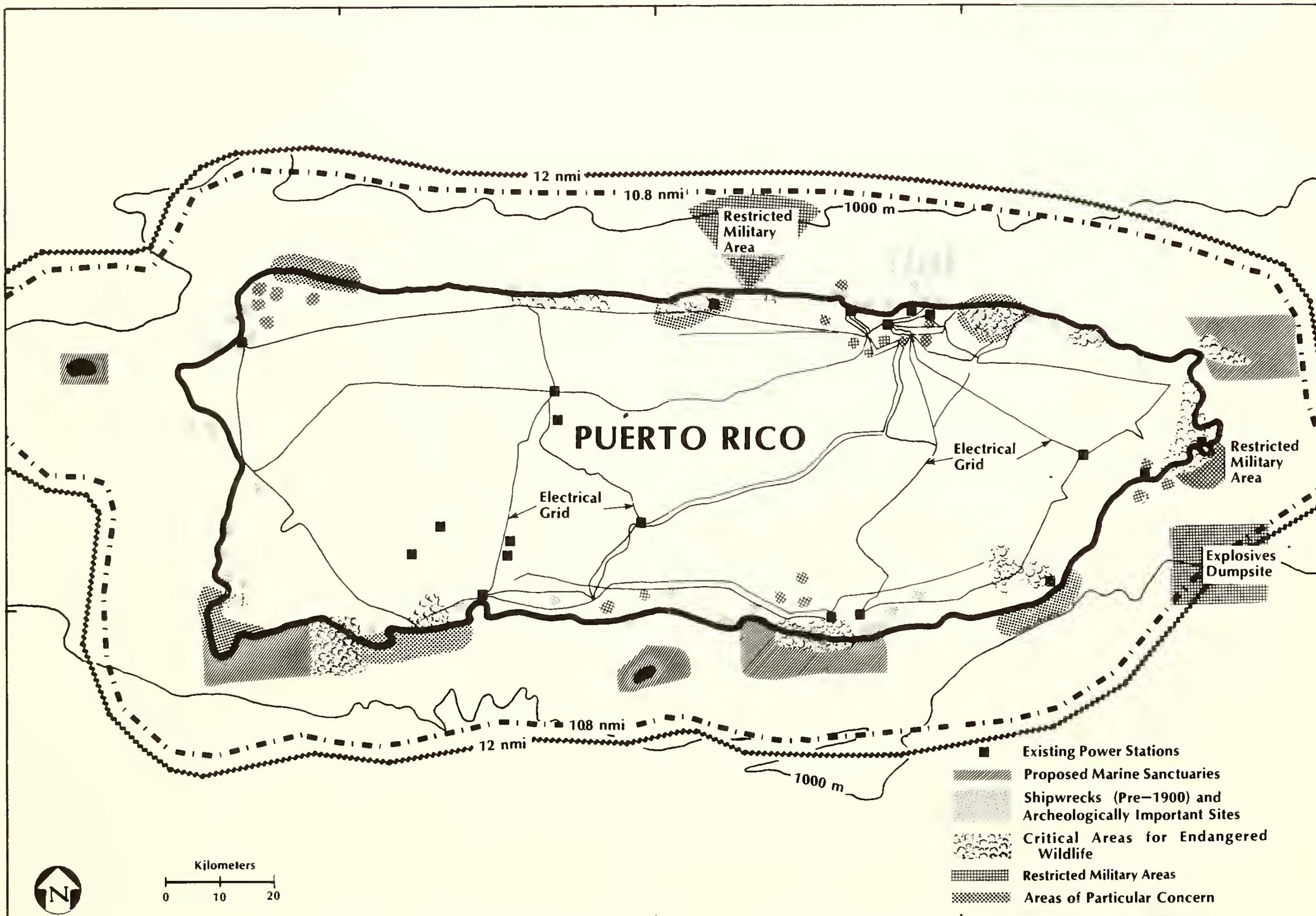


Figure 3-9. Existing-Use Areas in Puerto Rico

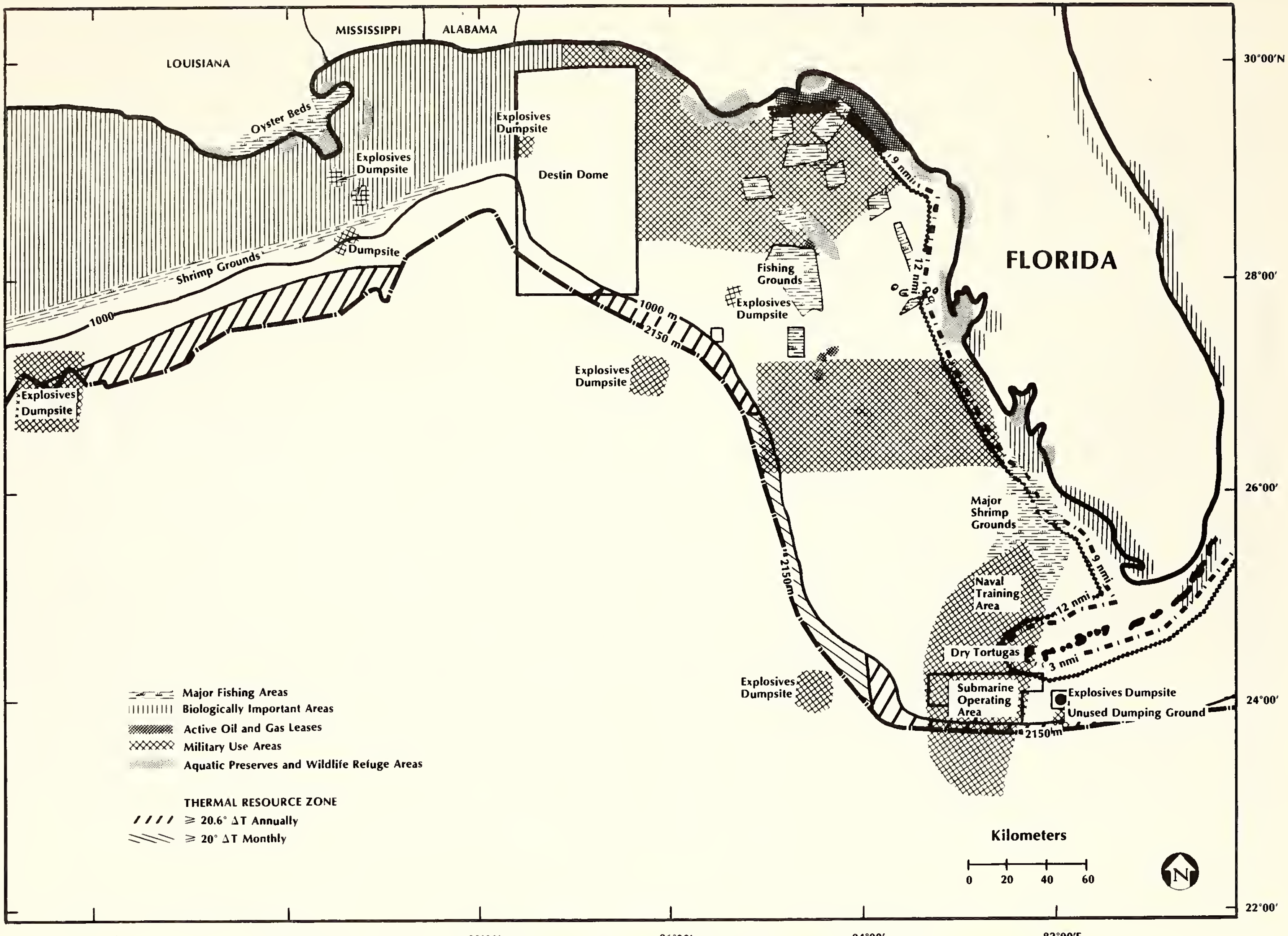


Figure 3-10. Existing-Use Areas in the Eastern Gulf of Mexico

TABLE 3-6. CURRENT JURISDICTIONAL BOUNDARIES IN OTEC AREAS

Area	Territorial Sea (nmi)	Contiguous Zone (nmi)
Saint Croix	3	12
West Coast of Florida	9	12
Guam	3	12
Puerto Rico	10.8	12
Hawaii	3	12

candidate sites described, and the degree to which the area has been developed by man identified. Special consideration should be given to identifying any threatened and endangered species potentially affected by construction activities.

3.4.2 Description

Five candidate sites represent typical environments in which the construction of land-based OTEC plants is most likely to occur. These sites include Punta Tuna, Puerto Rico; Kahe Point, Oahu; Ke-ahole Point, Hawaii; Guam; and Saint Croix, Virgin Islands. Although each proposed area has a unique terrestrial environment, with minor differences in topography and meteorology, similarities between the individual communities do exist. All are tropical island communities originally formed as a result of volcanic activity. Each supports an extensive flora and fauna with many endemic species, several of which are classified as threatened or endangered (Table 3-7). The coastlines of the candidate sites range from minimally to extensively developed, with limited access to the shoreline. Populations near candidate sites are small (except Guam and Oahu), and economies are based primarily on agriculture and fishing. A brief description of these candidate land-based OTEC areas are presented in the following subsections to illustrate the diversity of terrestrial environments.

TABLE 3-7. THREATENED AND ENDANGERED SPECIES OF THE OTEC RESOURCE AREA (TERRESTRIAL)
Source: Sands, 1980.

Scientific Name	Common Name	Status	Distribution
	Crocodiles and Alligators		
Crocodylus acutus	American crocodile	E*	South Florida
Crocodylus novaequineae mindorensis	Philippine crocodile	E	Philippines (and Palau, TTPI**?)
Crocodylus rhombifer	Cuban crocodile	E	Cuba (Caribbean?)
Alligator missise-ippiensis	American alligator	T	Southeastern United States
	Other Reptiles		
Cyclura pinquis	Anegada Island ground iguana	E	Virgin Islands
Cyclura stejnegeri	Mona Island ground iguana	T***	Puerto Rico
Epicrates inornatus	Puerto Rican boa	E	Puerto Rico
Ameiva polops	St. Croix ground lizard	E	St. Croix, Virgin Islands
	Amphibians		
Eleutherodactylus jasperi	Goldon coqui	T	Puerto Rico
	Birds		
Acrocephalus familiaris kingi	Nihoa miller-bird	E	Nihoa, Hawaiian Islands
Psittirostra cantans cantans	Laysan finch	E	Laysan, Hawaiian Islands
Anas laysannensis	Laysan duck	E	Laysan, Hawaiian Islands
Anas wyvilliana	Hawaiian duck	E	Hawaiian Islands
Anas oustaleti	Marianas mallard	E	TTPI, Micronesia
Fulica americana alai	Hawaiian coot	E	Hawaiian Islands
Caprimulgus noctitherus	Puerto Rican whip-poor-will	E	Puerto Rico
Amazona vittata	Puerto Rican parrot	E	Puerto Rico
Columbia inornata wetmorei	Plain pigeon	E	Puerto Rico
Agelaius xanthomus	Yellow-shouldered blackbird	E	Puerto Rico
Falcon peregrinus anatum	American peregrine falcon	E	North American, Carribean
Himantopus himantopus knudseni	Hawaiian stilt	E	Hawaiian Islands
Gallinula chloropus sandvicensis	Hawaiian gallinule	E	Hawaiian Islands
Branta sandvicensis	Hawaiian goose	E	Hawaiian Islands

*Endangered
**Trust Territories of the Pacific Islands
***Threatened

3.4.2.1 Punta Tuna, Puerto Rico - Punta Tuna is located in the Maunabo Valley in southeast sector of Puerto Rico. The coastline is relatively level with numerous rivers and streams. Annual rainfall is about 25 cm per year. The landscape is forested but not tropical, and supports a myriad of wildlife (DOC, 1978c). Cultivation of sugar cane is the predominant land use. Extensive irrigation canals are present as a result of farming.

3.4.2.2 Kahe Point, Oahu - The substrate at Kahe Point is primarily composed of coarse gravel and coral sand, underlain by coral reefs. Annual rainfall is less than 25 cm per year. Vegetation near Kahe Point can be broken into 3 basic types: (1) a closed forest, consisting of trees 5-7 m in height and uniform in distribution, (2) an open forest where trees are scattered and a ground cover of herbs and grass exist, and (3) an open scrub grassland, where trees are sparsely scattered, and numerous scrubs and tall grasses are present. (Hawaiian Electric Company, 1973). No terrestrial threatened or endangered species are present near Kahe Point. Land use is primarily agricultural; however, some lands in the valley are designated as county and state parks and beaches. The Nanakuli Beach Park, the largest park in the area, encompasses 40 acres of the coastal zone north of the Kahe Electrical Generating Station.

3.4.2.3 Ke-ahole Point, Hawaii - Ke-ahole Point is located on the Kona coast of Hawaii. The coastline is somewhat level; however, some irregularities occur. Lava is the primary substrate, with its depth varying from 0.3 to 30 m. Annual rainfall is about 6 cm per year. Ground cover is sparse and conditions are semi-desert. Candidate land-based OTEC sites can be divided into three habitats: (1) the beach zone, containing an extremely diverse plant life; (2) a northern area, termed "new lava", comprised of sparse scattered vegetation; and (3) the remaining area, termed "old lava", comprised of dry grasses and herbs (R. M. Towill, 1976).

3.4.2.4 Guam - The shoreline configuration of Guam is rocky coastline with sandy beach. The rocky coastlines comprise 62% of the coast and the sandy beaches 32%. Four terrestrial ecosystems, located along the southeastern shores and on the northern half of the island, are presently being considered

as potential APC's. These unique ecosystems include wildlife refuges, limestone forests, pristine ecological communities, and critical habitats (DOC, 1978a). Each of these areas supports numerous types of native plants in addition to many endangered plants and animals.

3.4.2.5 Saint Croix, Virgin Islands - The north and west coasts of Saint Croix, the most likely areas for installation of land-based OTEC plants, are characterized by coastal plains and drowned estuaries which have since become mangrove lagoons (DOC, 1979b). The annual rainfall is about 16 cm per year. Extensive alteration of the island's ecosystem, sugar cane agriculture, and subsequent regrowth of vegetation have eliminated any free flowing streams that once existed. There is endangered species critical habitat for leatherback turtles at Sandy Point, St. Croix.

Chapter 4

ENVIRONMENTAL CONSEQUENCES

Commercial OTEC facilities and plantships may affect air quality, the terrestrial environment, the marine ecosystem, and human activities in the vicinity of deployment and operation sites. A quantitative and qualitative assessment of major, minor, and potential environmental effects associated with commercial OTEC development is presented, along with a summary of measures for reducing the magnitude of those effects that may cause adverse environmental impacts.

Commercial OTEC development may affect the atmosphere, the terrestrial environment, the marine ecosystem, and human activities in the vicinity of deployment and operation sites. The net environmental impacts resulting from commercial OTEC development are expected to be minimal compared to the impacts from fossil-fuel and nuclear power production; however, commercial OTEC development may result in significant environmental disturbances. Environmental effects that may result from commercial OTEC development can be related to specific plant activities. These activities and their associated environmental effects include:

Platform presence	Biota attraction or avoidance
	Protective hull-coating release
	Low-frequency sound
	Pipe and transmission cable implantation
	Interference with existing uses
	Aesthetic impact
Warm- and cold-water withdrawal	Organism impingement
	Organism entrainment

Water discharge	Biocide release
	Ocean water redistribution
	Working fluid release
	Trace constituent release
	Sea-surface temperature changes
	Carbon dioxide release

Evaluation of potential environmental impacts associated with commercial OTEC development is presently a matter of speculation; little data has been collected near an operating OTEC plant (Sullivan et al., 1980). During the first deployment of Mini-OTEC at Ke-ahole Point, Hawaii, the number and species of fish attracted to the platform were monitored, chemical samples were obtained, and discharge plume observations were made (Donat et al., 1980). Environmental monitoring for the *Ocean Energy Converter* (OTEC-1), also near Ke-ahole Point, has begun (Menzie et al., 1980), but it is presently too early in the monitoring program to evaluate the results. Oceanographic surveys are being conducted under Department of Energy (DOE) funding at candidate OTEC sites (Table 4-1) to provide preliminary information for future studies (Wilde, 1980). Physical models are being developed to predict OTEC plume dilution and dispersion and examine recirculation potentials from various discharge configurations (Ditmars et al., 1980). Zooplankton and fish toxicity studies are underway at the Gulf Coast Research Laboratory (GCRL) and will provide information on organism tolerance to chlorine and ammonia releases (Venkataramiah, 1979).

Several reports have made preliminary assessments of the potential environmental effects associated with OTEC plants. The full range of environmental issues surrounding OTEC development, demonstration, and commercialization was described in the DOE OTEC Environmental Development Plan (DOE, 1979a). An Environmental Assessment (EA) was prepared (DOE, 1979b) and supplemented (Sinay-Friedman, 1979) for OTEC-1. A draft of the OTEC Programmatic EA, considering the environmental effects of the development, demonstration, and commercialization of several OTEC plant designs, configurations, and power usages, has been completed (Sands, 1980). A site- and design-specific EA was prepared for the proposed second deployment of Mini-OTEC (Donat et al.,

TABLE 4-1
STATUS OF OTEC OCEANOGRAPHIC SURVEYS
(NUMBER OF SITE OCCUPATIONS)
Source: Wilde, 1980

Site	Physical Measurements	Chemical Measurements	Biological Measurements
Gulf of Mexico	8	6	6
South Atlantic	4	2	2
Puerto Rico	10	7	8
Virgin Islands	0	1	1
Hawaii - Ke-ahole Point	11	8	8
Oahu - Kahe Point	4	4	4

1980), and a generic EA has been completed for the 40-MWe OTEC Pilot Plant Program (Sullivan et al., 1980).

This section quantitatively and qualitatively assesses the potential atmospheric, terrestrial, and marine impacts associated with commercial OTEC development. The potential for atmospheric, terrestrial, and marine effects resulting from commercial OTEC development are considered in Sections 4.1, 4.2, and 4.3, respectively. The effects of commercial OTEC development on human activities are discussed in Section 4.4. Indirect and cumulative environmental effects of commercial OTEC development are summarized in Sections 4.5 and 4.6, respectively. Section 4.7 identifies unavoidable adverse effects associated with commercial OTEC development and describes mitigating measures for reducing impacts. Section 4.8 discusses the relationship between short-term use and long-term productivity, and Section 4.9 describes the commitment of resources.

4.1 ATMOSPHERIC EFFECTS

OTEC operations may affect local air quality and climate. Air quality may be affected by emissions from OTEC plantships and electrical-generating facilities. OTEC operation could affect local and global climate as a result of carbon dioxide release and sea-surface temperature alterations. Carbon dioxide releases from degassing of seawater and industrial processing by OTEC plants may contribute to the warming of the atmosphere. Sea-surface temperature alterations resulting from ocean water redistribution may influence storm frequencies.

Under normal operating conditions, OTEC electrical-generating plants will release few emissions to the atmosphere and will not adversely affect local air quality. Industrial OTEC plantships, which produce energy-intensive products (e.g., ammonia, aluminum), will reduce gaseous releases to the atmosphere through byproduct recycling and the use of scrubbers. A catastrophic accident could release large volumes of working fluids which would vaporize to the atmosphere and cause short-term air quality effects; however, accidents of this magnitude will be extremely rare.

The carbon dioxide concentration in the earth's atmosphere is increasing (Brewer, 1978), which may be causing average global temperatures to increase through the greenhouse effect. Seawater degassing and industrial processing by OTEC plants are not expected to cause a significant increase in atmospheric carbon dioxide. The amount of carbon dioxide efflux from a 400-MWe closed-cycle OTEC plant has been estimated to range from 1500 to 2500 metric tons per day (Sands, 1980), which is approximately 25% of the carbon dioxide that a 400-MWe coal-fired plant produces (Ditmars, 1979). An aluminum-producing plantship will emit an additional 930 metric tons of carbon dioxide per day as a result of the manufacturing process (Appendix D). A 40-MWe open-cycle OTEC plant, could release 2300 metric tons of carbon dioxide per day (Appendix D), roughly 10 times as much as a similar-sized closed-cycle OTEC plant, or about 2.5 times the carbon dioxide released from a 40-MWe coal-fired plant. The projected OTEC operation by the year 2000 would release about 28 x 10^6 metric tons of carbon dioxide per

year. Although OTEC operations will add carbon dioxide to the atmosphere, this contribution is insignificant when compared to the 18 x 10^9 metric tons of carbon dioxide added yearly from fossil fuel consumption (Brewer, 1978).

Potential sea-surface temperature alterations by OTEC plants have caused environmental concern because climatic changes resulting from small (less than $1^{o}C$) sea-surface temperature changes over large ocean areas (greater than 1000 km^2) have been reported (Barnett, 1978; Davis, 1978; White and Haney, 1978; Namias, 1979). Two aspects of OTEC plant operation will decrease sea-surface temperatures: (1) large quantities of cold water will be brought to the surface for use in a plant's condenser units and be discharged into the surrounding water column after use, and (2) large quantities of warm water will be drawn across the evaporators and cooled by several degrees before being discharged to the receiving waters. If the discharged waters remain within the mixed layer, the sea-surface temperature will be altered, potentially causing climatic changes.

The magnitude of the sea-surface temperature alteration will be determined by the size of the plant, the discharge mode, the site, and the mixed-layer depth. Several potential OTEC sites (e.g., Gulf of Mexico) are located in source regions of tropical cyclones. Since these areas are sensitive to changes in sea-surface temperature, OTEC operations could alter storm frequency by increasing or inhibiting storm production. Altering storm frequency could significantly affect distant regions to which storms migrate.

The magnitude and nature of climatic effects resulting from sea-surface temperature alterations by commercial OTEC development have not been ascertained; additional research is required to assess the magnitude of this effect. Bathen (1975) estimated the area of heat loss associated with the operation of 100-MWe and 240-MWe OTEC plants off Hawaii and concluded that sea-surface temperature anomalies greater than the natural diel temperature fluctuations ($0.1^{o}C$ to $0.3^{o}C$) could occur, but these temperature changes were less than the seasonal variation of about $1^{o}C$. The area over which this temperature anomaly would spread was insignificant when compared to the

size of areas required for changes in large-scale weather patterns. Estimates of sea-surface temperature depression caused by the operation of one hundred 200-MWe OTEC plants in the Gulf of Mexico indicate that the average sea-surface temperature could decrease by about 0.05°C over the entire Gulf of Mexico (Martin and Roberts, 1977), which could potentially have climatic implications. A numerical model of the Gulf of Mexico is being prepared by Dynalysis of Princeton under DOE funding, and will provide information on the effect of OTEC operation on sea-surface temperatures and weather patterns over large ocean areas.

4.2 TERRESTRIAL EFFECTS

Construction of land-based OTEC plants will have similar effects on coastal-marine and terrestrial environments as building fossil or nuclear power plants along the coast. The magnitude of these disturbances will be determined by the proximity of ecologically-sensitive areas, the nature of the existing biological and physical environment, the design of the OTEC plant, the accessibility of the site, and the proximity of the site to the resources required for plant construction. Land-based plants should be sited to minimize impacts on historically-, culturally-, and ecologically-sensitive areas. Maximum effects to both land and biota will occur during the initial staging phase of construction and diminish as the plant nears completion. Permanent effects will be limited to the actual plant site and access routes necessary for the operational workforce. Temporary effects will result from the implantation of the warm- and cold-water pipes, connection of the OTEC facility to existing utilities, and noise, fumes, and dust associated with construction activities.

Construction of land-based OTEC plants consist of three phases: (1) a staging phase, in which the site is prepared for the incoming workforce and equipment, (2) a construction phase, in which the plant and any other required construction is completed, and (3) a completion phase, where cleanup of the site occurs and preliminary operational testing of the facility begins. A cursory description of the potential effects of these phases is

presented in the following subsections. A further assessment of impacts is not possible until specific plant locations and design details have been determined.

4.2.1 Staging Phase

The staging phase involves the construction of access roads, storage areas, and housing facilities. Access roads leading to the construction site must be built or sufficiently renovated to withstand traffic from heavy construction equipment.

The primary effects from the staging phase will include ground cover removal, habitat destruction, and material disposal. These changes to the terrestrial environment may alter watershed runoff patterns and increase the accessibility of the area. Any associated terrestrial impacts will be localized and mitigating measures required by Federal, State, and local regulations.

4.2.2 Construction Phase

Upon completion of the staging phase, construction of the power plant and its components will begin with the manufacture and implantation of the cold- and warm-water pipes and the excavation of heat exchanger troughs. These activities will require extensive modification of the coastal region since the pipes and heat exchangers must be placed approximately 20 m below sea level (Brewer et al., 1979). Some of the candidate sites are located on a lava base and blasting may be required. The construction phase will result in increased noise levels and habitat disruption to the surrounding land and adjacent waters, which could potentially damage or kill biota in the immediate vicinity.

4.2.3 Completion Phase

Upon completion of the facility, areas surrounding the plant may be restored to their original form. Lands adjacent to the facility, the coastal region of pipe implantation, and all utility corridors will be landscaped. Permanent effects to the surrounding areas will result from an increase in human presence, the maintenance of access roads, and noise from plant operation. Proper plant siting and design will minimize these effects.

4.3 MARINE EFFECTS

The majority of environmental effects associated with commercial OTEC development center on the marine ecosystem because it is the source of evaporating and condensing waters and receiver of effluent waters used by OTEC plants. Marine environmental effects associated with commercial OTEC development (Figure 4-1) can be categorized as: (1) major (those potentially causing significant long-term environmental impacts), (2) minor (those causing insignificant long- or short-term environmental changes), and (3) potential (short-term impacts occurring only during accidents). OTEC activities that cause environmental effects corresponding to these categories include:

Major Effects:

- Platform presence - Organism attraction or avoidance
- Withdrawal of surface and deep-ocean waters - Organism entrainment and impingement
- Biocide release - Organism toxic response
- Discharge of waters - Nutrient redistribution, resulting in increased productivity

Minor Effects:

• Protective hull-coating release	- Toxic effects and bioaccumulation of trace metals
• Power cycle component erosion and corrosion	- Toxic effects and bioaccumulation of trace constituents
• Implantation of cold-water pipe and transmission cable	- Short-term habitat destruction and turbidity during implantation
• Low-frequency noise	- Interference with organism behavior and communication
• Discharge of surfactants	- Toxic effects to resident organisms
• Open-cycle plant operation	- Alteration of oxygen and salt concentration of downstream waters

Potential Effects from Accidents:

• Potential working fluid release from spills and leaks	- Organism toxic response
• Potential oil releases	- Organism toxic response

A description of the downstream plume behavior is essential for assessing the major, minor, and potential effects of commercial OTEC development. A generalized summary of the predicted plume behavior from commercial OTEC plants is presented in Subsection 4.3.1. The major, minor, and potential (accidental) environmental effects associated with commercial OTEC development are quantitatively and qualitatively discussed in Subsections 4.3.2 through 4.3.4.

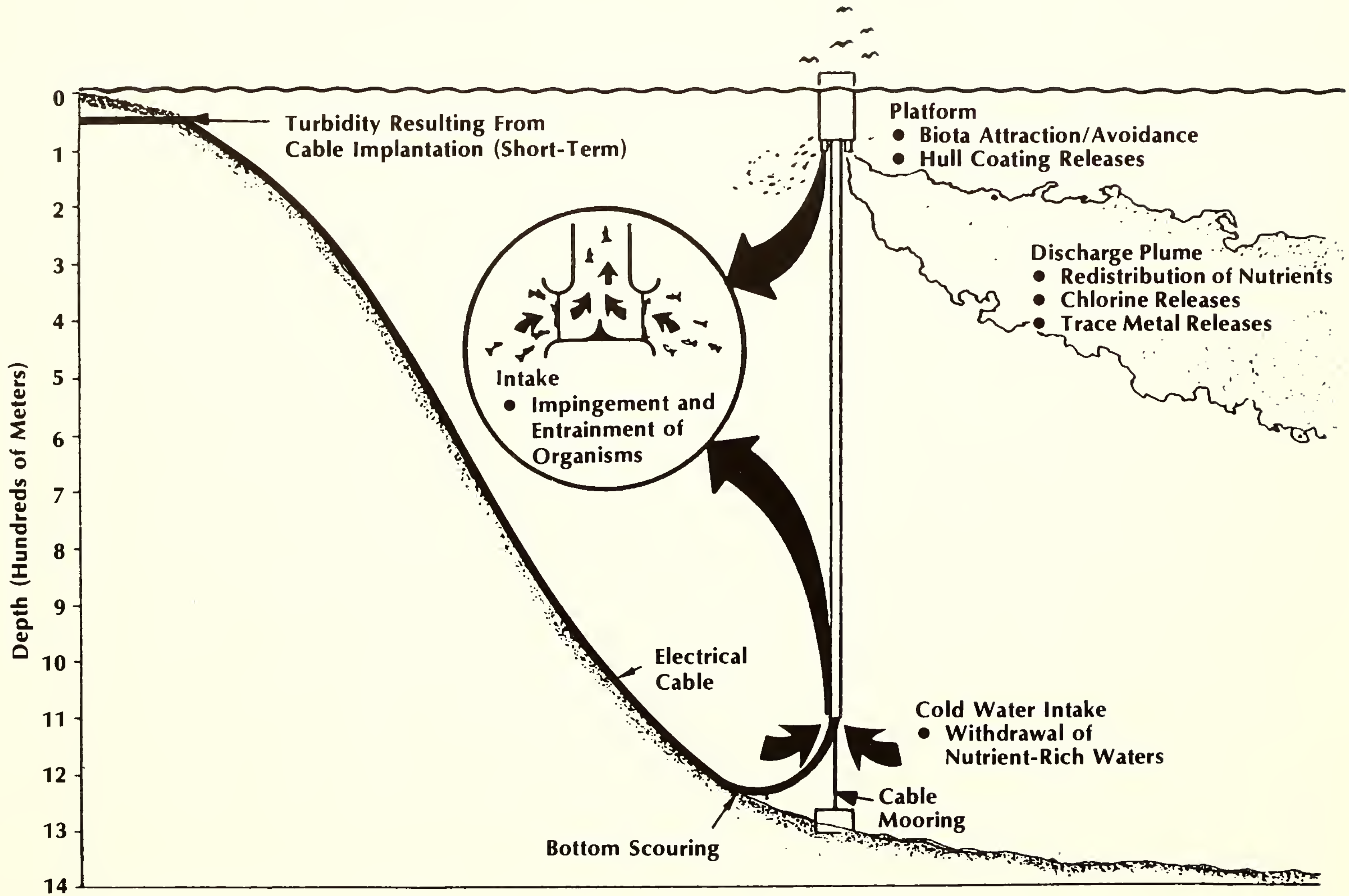


Figure 4-1. Environmental Effects of OTEC Operation
Source: Sullivan et al., 1980

4.3.1 Discharge Plume Description

As the OTEC discharge effluent enters the ocean, it will have a different density than the surrounding ambient water. The behavior of the discharge plume will be dominated by the discharge momentum and buoyancy forces resulting from the initial density difference (Figure 4-2). Within several hundred meters from the point of discharge, the discharge plume will: (1) be diluted by the ambient ocean water, (2) sink or rise to reach an equilibrium level within the water column where the average density difference between the diluted plume and surrounding ambient water vanishes, and (3) lose velocity until the difference between the plume's velocity and the ambient current velocity is small. This initial region is referred to as the near-field regime (Ditmars and Paddock, 1981).

When the discharge effluent from the plant has reached its equilibrium depth, it has lost its jet-like characteristics and has a velocity only slightly different than the ambient current; this region is referred to as the intermediate-field regime. The intrusion of the effluent into the stratified ocean causes the plume to collapse vertically due to residual buoyancy forces and spread laterally due to gravity forces. The interaction of the spreading layer and the ambient current in the near-field produces a plume that extends upcurrent of the plant and grows in width downcurrent due to gravity spreading until gravity forces become small and turbulent diffusion takes over as the dominant mixing process (Ditmars and Paddock, 1979).

Mixing in the intermediate-field is greatly reduced compared to the near-field region. The magnitude of the ambient current dominates the behavior of the discharge plume in the intermediate-field, although local ambient density stratification and initial near-field dilution will have some influence on the width and thickness of the resultant plume. Further downstream, buoyancy-driven motions become small and diffusion (by means of ambient turbulence in the ocean) becomes the dominant mixing and spreading mechanism. This region of passive turbulent diffusion is referred to as the far-field regime.

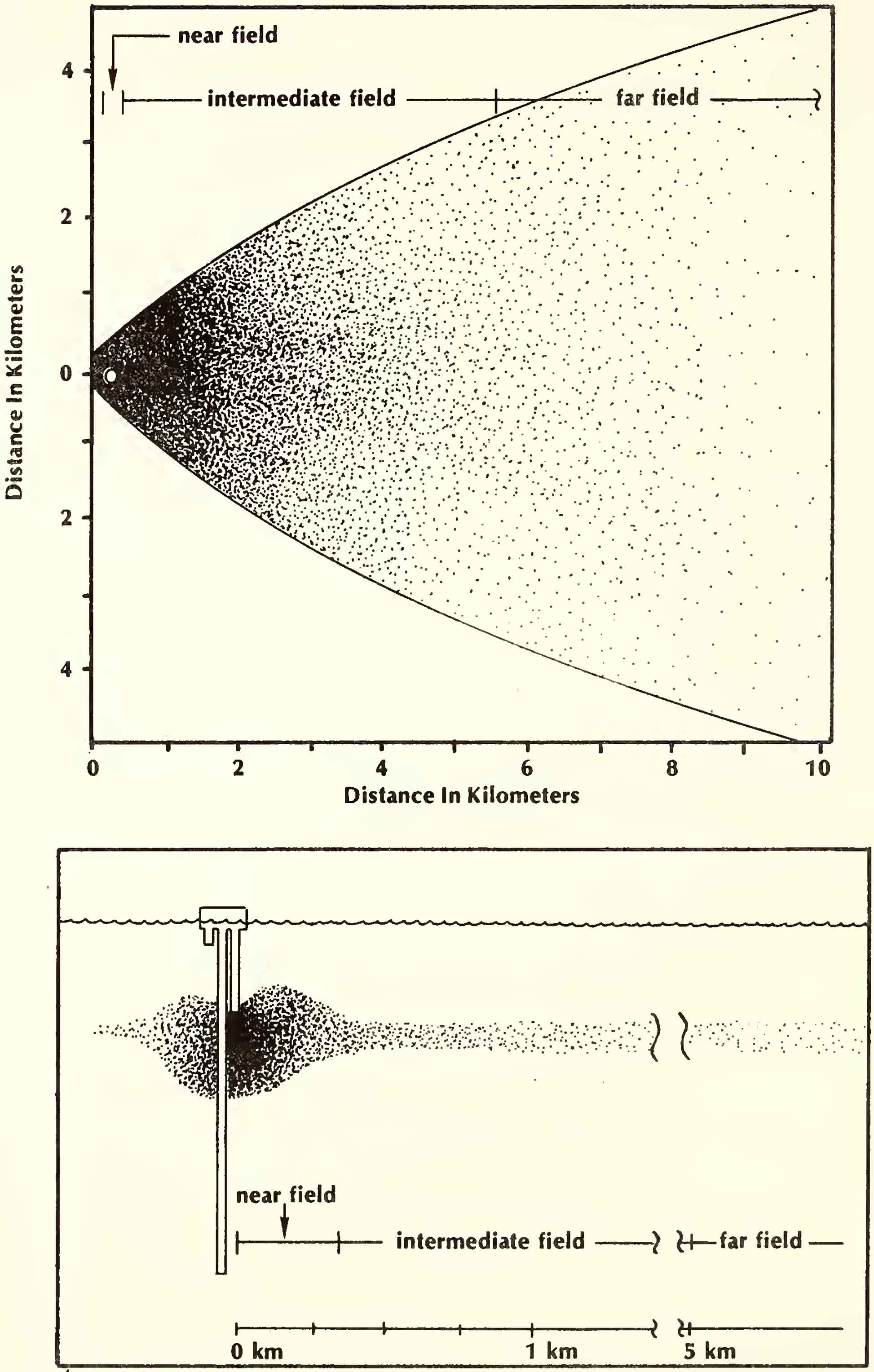


Figure 4-2. Generalized Diagram of a Mixed Discharge Plume. Ambient current velocity assumed to be 100 cm sec^{-1}.

Predicting the detailed external flow field in the near-field region of OTEC discharge plumes is complicated by the strong influence that the discharge-structure design, ambient currents, water column stratification, and proximity of the warm-water intake to the outfall have on plume behavior. Schematic laboratory-scale experiments on OTEC discharge plume behavior have been conducted by Sundaram et al. (1977, 1978) and Jirka et al. (1977, 1980); detailed physical model tests are currently underway (Adams et al., 1979; Coxe et al., 1981). These studies indicate that, in the case of separate evaporator and condenser discharges, the density of the evaporator effluent will be only slightly above ambient if discharged into the mixed layer. The plume will reach its equilibrium level within the mixed layer if discharged horizontally, or slightly below the mixed layer if initially directed downward. The condenser effluent will be strongly negatively-buoyant, but mixing with ambient water in the mixed layer will cause the condenser effluent to reach an equilibrium level only slightly below the mixed layer (within the thermocline). If discharged vertically below the thermocline, mixing will prevent the condenser effluent from sinking more than 50 to 100 m below the point of discharge. A combined- or mixed-discharge effluent will behave much like the condenser effluent, except that the equilibrium depth will probably be slightly higher due to the smaller initial density difference.

Although the near-field dilution will vary with the discharge structure design and ambient environmental conditions, near-field dilution will range between 5-10 for currents below 50 cm sec^{-1} and 15-20 for currents between 80 and 100 cm sec^{-1}. Once the diluted OTEC effluent has reached the equilibrium level in the intermediate-field, plume spreading is governed by current velocity and strength of the ambient water column stratification. In areas with low current velocities (approximately 10 cm sec^{-1}), the plume will be 10-12 km wide and approximately 20 m thick within 10 km downstream of the plant. Large currents (approximately 100 cm sec^{-1}) would produce narrow plumes only 1 km wide at 10 km downstream of the plant (Ditmars and Paddock, 1981). The discharge plume will have to travel several hundred kilometers in the far-field region in order to obtain additional dilution comparable to the original near-field dilution of 5-10.

4.3.2 Major Effects

Major environmental effects of commercial OTEC development may potentially cause significant environmental impacts. These major effects, including biota attraction and avoidance, organism entrainment, organism impingement, biocide release, and nutrient redistribution, are described in the following subsections.

4.3.2.1 Biota Attraction and Avoidance - OTEC plants will attract epipelagic organisms similar to those that concentrate around offshore structures, floating objects, and artificial reefs (Carlisle et al., 1964; Wickham et al., 1973; Gooding and Magnuson, 1967; Hastings et al., 1976). Motile organisms will be attracted by the plant structure and nighttime illumination of the plant (Wickham et al., 1973; Isaacs et al., 1974; Longhurst, 1976), while weakly swimming and nonmotile organisms will settle on the plant. As a result of new habitat formation, populations near the plant will increase, compounding the magnitude of environmental impacts associated with OTEC deployment and operation. Conversely, organisms sensitive to human activities and presence may avoid OTEC areas as a result of construction activities, plant operational support activities, and plant operation noise.

Siting of OTEC plants is a critical consideration for reducing the effects from biota attraction and avoidance. In nearshore environments, platform attraction rates will be rapid (Figure 4-3) and include high concentrations of both neritic and oceanic biota. In contrast, an offshore OTEC platform will attract lower numbers of organisms, primarily through opportunistic encounters. Multiple plant deployments could result in higher numbers of attracted organisms because the new habitat formed may be larger than the sum of the habitats produced by individual plants. Biota avoidance of OTEC plants will have a greater effect in nearshore environments than in offshore environments because nearshore organisms are generally less motile and have more restricted habitats. OTEC plants should be sited away from breeding grounds, calving areas, and migration routes of sensitive organisms.

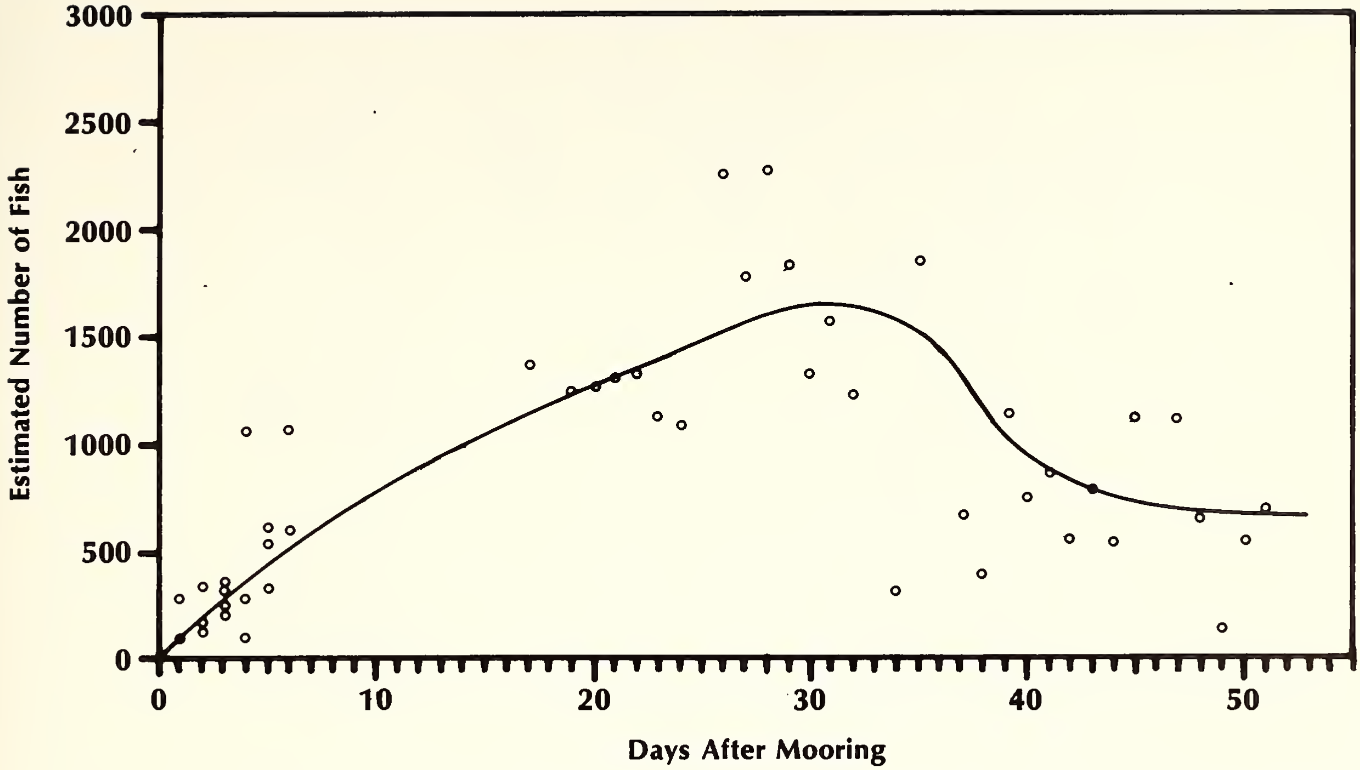


Figure 4-3. Rate of Fish Attraction to Floating Objects in Tropical Nearshore Waters
Source: Hunter and Mitchell, 1967

4.3.2.2 Organism Entrainment - Small marine organisms will be withdrawn from the water column and passed through OTEC plants. Organisms withdrawn at the cold-water intake are expected to suffer 100% mortality as a result of the physical abuse, large temperature (20^{o}C) and pressure (100 atmosphere) changes, and biocidal stress associated with passage through the plant. Similarly, survival of organisms withdrawn by the warm-water intakes of open-cycle, hybrid, mist, and foam OTEC plants will be negligible; however, survival of organisms withdrawn by the warm-water intake of closed-cycle OTEC plants may be possible.

Preliminary estimates (Table 4-2) indicate more organisms will be entrained at the warm-water intake than at the cold-water intake because the concentration of plankton in tropical oceanic environments decreases dramatically

TABLE 4-2
ESTIMATED BIOMASS ENTRAINED DAILY BY VARIOUS SIZES AND NUMBER OF OTEC PLANTS
Source: Sands, 1980

Size of Operation	Intake	Phytoplankton Biomass Entrained (kg C)	Microzooplankton Biomass Entrained (kg C)	Macrozooplankton Biomass Entrained (kg C)
40-MWe	Warm-Water Intake	120	2.3	81.0
	Cold-Water Intake	0	0	5.4
	Total	120	2.3	86.4
400-MWe	Warm-Water Intake	1,200	24	830
	Cold-Water Intake	0	0	50
	Total	1,200	24	880
Cluster (8 Plants; 3200-MWe)	Warm-Water Intake	9,600	190	6,640
	Cold-Water Intake	0	0	400
	Total	9,600	190	7,040

below 300 m (Figure 4-4). Entrainment at the warm- and cold-water intakes will primarily affect macrozooplankton. Phytoplankton and microzooplankton populations will not be seriously affected by OTEC operation because the majority of their biomass is concentrated between the warm- and cold-water intake depths (Lawrence Berkeley Laboratory, 1980; Beers, 1978). The ecological impact of macrozooplankton entrainment is difficult to predict because knowledge on the dynamics of the tropical-subtropical ecosystem (i.e., trophic relationship, population dynamics, and community structure) is incomplete. However, the mortality of a large percentage of the macrozooplankton population within an area could affect higher trophic levels and potentially become apparent to man through a reduction in commercial fisheries.

Entrainment of the eggs and larvae of benthic invertebrates (meroplankton) and fish (ichthyoplankton) may be the single-most serious biological impact resulting from commercial OTEC operation. Preliminary estimates indicate

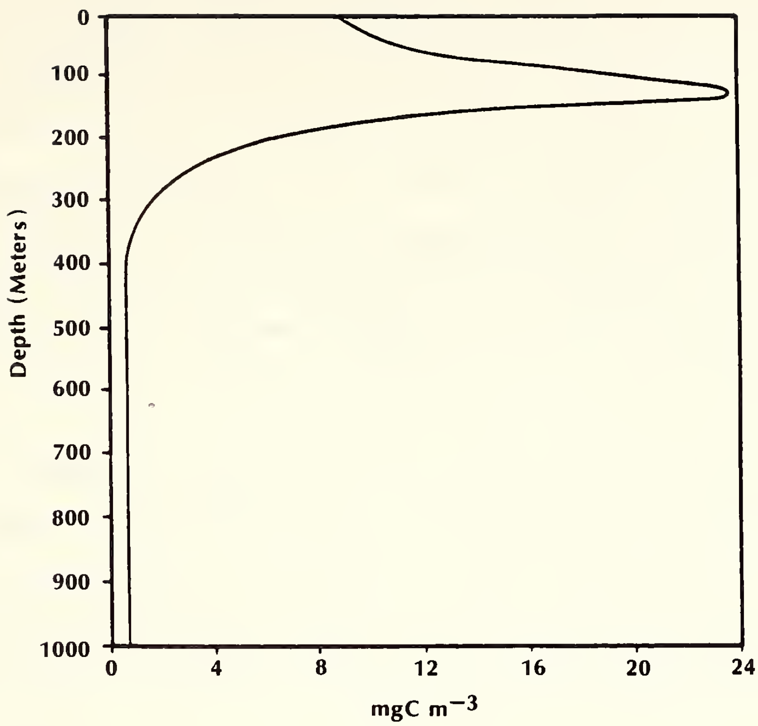


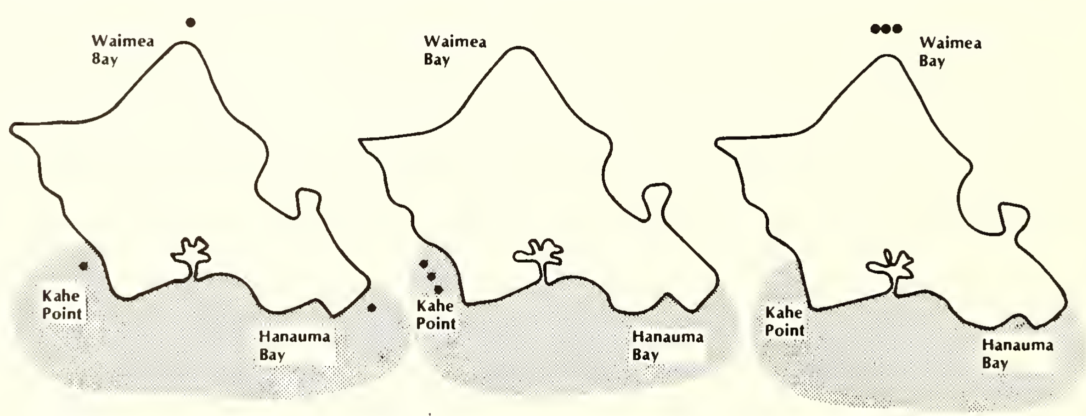
Figure 4-4. Biomass of Potentially-Entrained Phytoplankton and Zooplankton Between the Surface and 1000 m.
Source: Data from Johnson and Horne (1979); King and Hida (1954).

that entrainment of eggs and larvae by commercial OTEC plants may significantly impact the adult population of ecologically- and commercially-important species (Sands, 1980; Sullivan et al., 1980). This is of particular concern around islands where maintenance of local larval populations is vital to adult population existence and limited recruitment stocks are available. It has been estimated that a 400-MWe OTEC plant would entrain daily approximately 0.05 percent and 0.2 percent of the total meroplankton biomass around the Hawaiian Islands and Puerto Rico, respectively (Sands, 1980), eventually causing a reduction in the adult benthic invertebrate population downstream of the plant.

Entrainment of ichthyoplankton by commercial OTEC plants may significantly affect fishery resources in the vicinity of the operation site. The effects of ichthyoplankton entrainment on the fisheries of Oahu, Hawaii, were

predicted for three different deployment scenarios (Figure 4-5). Three commercially-important fish were investigated (Appendix D); however, only the commercially-important amberjack (*Seriola* sp.) is discussed here as an example which best illustrates siting and spacing considerations. Clustering of OTEC plants near a spawning area could cause a loss of a potential fishery resource equivalent to $67,000 per year. In contrast, clustering of OTEC plants in an area of low larval abundance could cause a negligible threat to the island's fishery resources. Scattered plant spacing may cause an impact of intermediate magnitude because larval abundance varies greatly with geographic location.

Another entrainment issue concerns the secondary entrainment of organisms into the discharge plume. Because of the large discharge volumes and rapid near-field dilution, this secondary entrainment may be significant. A vertically oriented discharge structure would provide secondarily entrained waters with a net downward momentum, which may transport the organisms below



Total Year^{-1}	Evenly Spaced Deployment	Cluster off Kahe Point	Cluster off Waimea Bay
Entrained Larvae	1.5×10^8	4.0×10^8	Negligible
Equivalent Adults	1500	4000	Negligible
Commercial Dollar Value	25,000	67,000	Negligible

Spawning areas

• 400-MWe OTEC Plant

See Appendix D for larval density information and catch statistics

Figure 4-5. Equivalent Number and Commercial Value of Adult Amberjack (*Seriola* spp.) Lost as a Result of Ichthyoplankton Entrainment with Various Deployment Scenarios.

their optimum habitat, strongly reducing their chances for survival. The effects from displacing organisms from the surface layers to deeper depths cannot be assessed with the available information, but could cause increased organism mortality.

4.3.2.3 Organism Impingement - Large marine organisms with limited avoidance capabilities will be subjected to impingement on intake screens of OTEC plants. Impingement may cause significant reductions in local fish, squid, and shrimp populations and could directly or indirectly affect the fishery resources of an area. Disposal of impinged organisms killed or damaged on the intake screens may result in increased feeding activity downstream of an OTEC plant. Impingement rates at conventional land-based generating plants were used to provide an order-of-magnitude estimate of potential impingement at a land-based OTEC plant. Extrapolating from existing data suggests that a 400-MWe land-based OTEC plant could impinge between 50 and 4400 kg of large motile nekton per day (Appendix D). Nekton impingement rates for OTEC plants cannot be precisely estimated because no impingement studies have been performed for offshore power plants.

Preliminary estimates indicate that micronekton (mesopelagic fish, squid, and shrimp) impingement will be higher for warm-water than cold-water intakes (Table 4-3) because micronekton vertically migrate from 500 m to concentrate near the surface at night. Micronekton impingement will indirectly affect nekton through food chain interactions since many commercially-important species of nekton (e.g., tuna) rely upon micronekton as a major food source. However, the direct and indirect effects of impingement on commercially-important species cannot be fully evaluated with the available data.

4.3.2.4 Biocide Release - OTEC plants may use biocides to control biofouling on the seawater side of heat exchanger surfaces. Biocides may adversely affect the local marine environment because of their toxicity to nontarget organisms and the large volumes that must be released to maintain heat exchanger efficiency (Sullivan et al., 1980). Candidate biocides include chlorine, chlorine dioxide, bromine chloride, and ozone. Evaluation of the effect of biocide release on the marine environment is difficult, because

TABLE 4-3
ESTIMATED BIOMASS (WET WEIGHT) IMPINGED DAILY
BY VARIOUS SIZES AND NUMBERS OF OTEC PLANTS
Source: Sands, 1980.

Size of Operation	Intake	Micronekton Biomass Impinged (kg)	Gelatinous Organism Biomass Impinged (kg)
40-MWe	Warm-Water Screen	130	8.3
	Cold-Water Screen	82	6.7
	Total	212	15
400-MWe (1 Plant)	Warm-Water Screens	1,300	84
	Cold-Water Screens	790	64
	Total	2,090	148
Cluster (8 Plants; 3200-MWe)	Warm-Water Screens	10,400	672
	Cold-Water Screens	6,300	512
	Total	16,700	1,184

insufficient information exists on the seawater chemistry, toxicity, and dilution rate of the various biocides within the discharge plume. Chlorine, the most likely biocide to be used in commercial OTEC plants, will be discussed as an example of the effects of biocide release because it is the most studied of the alternative biocides.

The chemistry of chlorine in seawater is complex (Opresko, 1980; Macalady et al., 1977; Block et al., 1976; Davis and Middaugh, 1975). In general, chlorine decays rapidly when exposed to sunlight, forming various organic and inorganic compounds that may persist for long periods of time. It is not possible to confidently predict the organic and inorganic compounds generated by chlorinating natural seawater (Block et al., 1977); however, more organic compounds may be formed than inorganic compounds (Zika, 1981). The organic compounds may be more toxic than either the inorganic compounds or the initially introduced chlorine (Zika, 1981). Chlorinated organic compounds are resistant to degradation and may be accumulated in organism tissues (Goldman, 1979).

Chlorine toxicity varies widely with the nature of the affected organism (Table 4-4). In general, phytoplankton are the most sensitive to chlorine, exhibiting a 50% reduction in photosynthesis after 24 hour exposures to concentrations as low as 0.075 mg liter^{-1} (Gentile et al., 1976). Planktonic larvae of benthic invertebrates (meroplankton) demonstrate a 50% mortality after a 96-hour exposure to chlorine concentrations as low as 0.005 mg liter^{-1} (Bender et al., 1977). Chlorine concentrations below 0.005 mg liter^{-1} are not likely to significantly affect marine organisms. As chlorine decays, the concentration of organic and inorganic compounds will increase, potentially reaching toxic levels. The lack of information on the toxicity of chlorine-seawater reaction products to marine organisms (Macalady et al., 1977; Opresko, 1980) hinders the further assessment of chlorine discharges. Sublethal effects of persistent chlorine-seawater reaction products may reduce the survivorship of organisms downstream of commercial OTEC plants.

The release of biocides by commercial OTEC plants could adversely affect the marine environment; therefore, unless other methods (e.g., thermal shock, abrasive cleaning, ultrasonics) are employed to control biofouling, an acceptable level of impact will have to be determined. For instance, if the region within 100 km of an OTEC plant can be affected without causing significant environmental disturbances, an initial chlorine concentration of less than 0.125 mg liter^{-1} at the discharge point would have to be maintained (assuming 25-fold dilution). If an OTEC plant can affect a 30 km region downstream of the plant without causing adverse impacts, the point source chlorine concentration would have to be limited to 0.06 mg liter^{-1} (assuming 12-fold dilution). In ecologically-sensitive areas, where the adverse effects associated with chlorine release are not acceptable, low (0.005 mg liter^{-1}) chlorine concentrations at the discharge point will be required. This may be possible by chlorinating heat exchanger modules individually and diluting the chlorinated effluent with chlorine-free effluent waters from the remaining heat exchanger modules which are not being chlorinated. These examples illustrate that determining biocide release concentrations and schedules will depend on the level of environmental disturbance NOAA is willing to accept at a particular site.

TABLE 4-4. TOXICITY OF CHLORINE TO MARINE ORGANISMS BASED ON 50% MORTALITY OR 50% DECREASE IN PRODUCTIVITY.
(Chlorine units in mg $liter^{-1}$).

Organism	Exposure Period (Hours) <1	2-4	4-12	24	48	96
Phytoplankton	0.1 [a] 0.2 [b] 0.2-0.8 [c] 0.49 [d]	0.09 [e] 0.1 [f]	0.033-0.24 [g]	0.075-0.33 [b]	No Data	No Data
Zooplankton (Holoplankton)	0.23-0.82 [h] 1.82 [i] 2.5-10 [b]	0.9 [j] 1.0 [b] 1.4-1.5 [i] 2.5 [k]	0.15 [j] 0.15-1.0 [b]	0.38 [m]	<0.05 [m]	0.090-0.178 [n] 0.22 [m]
Zooplankton (Meroplankton)	0.25-0.30 [o]	No Data	No Data	No Data	<0.005 [m] 0.005 [g]	0.005 [g] 0.024-0.12 [p]
Fish Larvae	0.70 [q]	0.075 [r] 0.22 [q]	0.05 [r]	0.19-0.32 [s]	0.037-0.062 [t] 0.17-0.21 [l] 0.20-0.24 [s]	0.028 [r] 0.040 [t]
Adult Fish	0.7 [q] 1.2 [u] 2.5 [b]	0.22 [q] 0.56-0.67 [u] 0.64 [m]	0.21 [u]	0.08-0.28 [m] 0.1 [b]	0.037-0.27 [m]	0.037-0.27 [m] 0.080 [t] 0.27 [s]

(a) Fox and Moyer, 1975
(b) Gentile et al., 1976
(c) Gentile, 1972
(d) Carpenter et al., 1972
(e) Davis and Coughlan, 1978
(f) Eppley et al., 1976
(g) Bender et al., 1977
(h) Goldman and Ryther 1976
(i) Ginn and O'Connor 1978
(j) Patrick and McLean .1970
(k) McLean 1973
(l) Johnson et al. 1977
(m) Roberts et al. 1975
(n) Thatcher 1978
(o) Capuzzo et al., 1977
(p) Roberts, 1978
(q) Fairbanks et al., 1971
(r) Alderson, 1974
(s) Morgan and Prince, 1977
(t) Alderson, 1970
(u) Engstrom and Kirkwood,

4.3.2.5 Nutrient Redistribution - The transport of large volumes of nutrient-rich deep water into surface layers by an OTEC plant is comparable to the natural phenomenon of upwelling. Increased nutrients in the surface layers of the water column may result in increased phytoplankton populations, thereby leading to the enhancement of zooplankton populations and the entire food chain. Entrained organisms killed during their passage through the plant provide on additional nutrient source as particulate organic carbon. Nutrient redistribution is expected to enhance biological productivity and potentially create valuable fishery resources; however, nutrient redistribution could stimulate toxic red tides that occur in certain regions of the OTEC resource area (i.e. Gulf of Mexico) .

The cold, nutrient-rich waters discharged by commercial OTEC plants may stabilize below the one percent light-penetration depth, where phytoplankton growth is limited. Therefore, increased productivity resulting from nutrient redistribution may not be an issue. However, if the cold, nutrient-rich water discharged from OTEC plants remains within the photic zone, enhanced primary production will result, potentially increasing phytoplankton biomass to 3 times the ambient concentration for a 40-MWe plant (Sullivan et al., 1980) and 30 times the ambient concentration for a 400-MWe plant (Sands, 1980).

Increases in phytoplankton biomass downstream of OTEC plants may result in changes to the existing marine food chain by making additional food available, thereby potentially increasing zooplankton and other higher trophic-level populations. An order-of-magnitude estimate indicates that the nutrients discharged by a 400-MWe OTEC plant in a day would sustain 4.1 kg of tuna through a long, oceanic food chain (Appendix D). However, increasing the productivity of an area may make the marine food chain shorter and more efficient. The same amount of nutrients as used in the previous example would sustain between 1,000 and 16,000 kg of tuna if shorter, more efficient food chains develop as a result of the upwelled waters (Appendix D). Therefore, commercial OTEC plants have the potential for artificially enriching downstream areas and supporting valuable fishery resources.

Increased productivity downstream of the plant could potentially result in adverse impacts. Within the phytoplankton, a group of dinoflagellates exists that cause the phenomenon known as red tide. Red tide refers to the discolored patches of seawater caused by large aggregations of dinoflagellates that produce a neurotoxin lethal to marine organisms (Lackey and Hines, 1955). Exact causes of red tides are not known, but an abundant nutrient source is required to sustain a bloom. The redistribution of nutrient-rich deep waters into the surface layers by an OTEC plant could potentially cause a red tide outbreak, especially in areas having a large population of red tide-producing organisms (i.e. Gulf of Mexico).

4.3.3 Minor Effects

Minor environmental effects result from OTEC activities that cause insignificant changes to the marine environment. These minor effects, including protective hull-coating and trace constituent releases, submarine cable and pipe implantation, and low-frequency sound production, are described in the following subsections.

4.3.3.1 Protective Hull-Coating Release - OTEC plants will use protective hull coatings on exposed surfaces to minimize biofouling. Protective hull coatings may contain heavy metal oxides, organic compounds, or thermoplastic paints as their toxic constituent. Protective hull-coating releases are not expected to cause acute (lethal) effects to marine organisms (Sands, 1980; Sullivan et al., 1980); however, chronic impacts resulting from bioaccumulation may occur.

Bioaccumulation, or the uptake and assimilation of toxic materials within organism tissues, occurs through absorption and ingestion (Phillips and Russo, 1978). Organisms in the immediate vicinity of the plant may be exposed to metal concentrations above background levels that could be absorbed through their skin or gill tissues. Organisms that have absorbed metals may be ingested by predators, thereby passing the metals to higher trophic levels within the food chain.

Bioaccumulation of metals in commercial fish and shellfish will probably not create a hazard to man (Table 4-5). Copper and zinc pose a low risk to humans because of their low toxicities and tendency to accumulate in non-edible tissues. Arsenic bioaccumulation in edible tissues of most fish is quite low; however, levels associated with shellfish can be high and may be toxic to humans. Mercury is readily accumulated in muscle tissues and is the most toxic of the four metals; for these reasons, the Federal government has restricted the use of mercury in protective hull coatings (Jacoby, 1981).

4.3.3.2 Trace Constituent Release - Trace constituent releases will occur from the seawater corrosion and erosion of structural elements within OTEC plants (e.g., heat exchangers, pump impellers, metallic piping). Heat exchangers, the major source of trace constituent releases from an OTEC plant, will be constructed of titanium, aluminum, or stainless steel, all of which have low toxicities to marine organisms and slow bioaccumulation rates (Table 4-6). In addition, preliminary estimates indicate that OTEC trace constituent release rates will be extremely low (Sands, 1980; Sullivan et al., 1980). Therefore, no adverse environmental effects are expected.

4.3.3.3 Cable/Pipe Implantation - The benthic community will be affected by bottom scouring from mooring lines and bottom trenching during implantation of submarine transmission cables and cold-water pipes. Bottom scouring will cause a small disturbance at depths greater than 300 m. Because of the relatively small area disturbed, and the low benthic productivity below 300 m, the surrounding benthic community will not be significantly impacted (Sullivan et al., 1980).

The effects of cable and pipe implantation include burial, turbidity-induced clogging of respiratory and feeding surfaces, and habitat destruction. These effects should not be serious except in ecologically-sensitive areas, such as spawning grounds and coral reefs. The effects of implantation must be fully assessed after the dredging route has been determined and before construction proceeds.

TABLE 4-5
RELATIVE HAZARDS PRESENTED BY CANDIDATE PROTECTIVE HULL-COATING MATERIALS
Source: Phillips and Russo, 1978.

Metal	Toxicity to Humans From Oral Ingestion	Bioaccumulative Tendency			Human Hazard Rating
		Freshwater Fish Muscle	Marine Fish Muscle	Marine Shellfish or Crustaceans	
Copper	Low	Low	Low	High	Low
Zinc	Low	Low	Low	High	Low
Arsenic	High	Low	High	High	Low
Mercury	Low	High	High	High	High

4.3.3.4 Low-Frequency Sound - OTEC plants may produce low-frequency sound as a result of pump operation, passage of water through intake tubes, and cavitation within the plant. The sound emitted from an OTEC plant could interfere with low-frequency signals used for communication among marine mammals and various other marine life forms. Information on the frequency and intensity of OTEC sound emission is not presently available. A study of the military implications and applications of OTEC operation (prepared for the DOE by Tracor, Inc.) contains information on sound output from OTEC operation; however, this study is not available for public review. Considering the numerous human-related sources of low-frequency sounds in the ocean, sound emitted from OTEC operation is not expected to have a significant impact on marine life (Appendix D). However, special consideration should be given to studying the effects of low-frequency sound from OTEC plants on the endangered humpback whale *(Megaptera novaeangliae)* during its winter breeding and calving activities near the Hawaiian Islands.

4.3.3.5 Surfactant Release - The environmental effects of discharging surfactants along with the effluent from OTEC foam power plants is not known. Various surfactants are currently being tested at the Carnegie-Mellon University (Noriega, 1981); presently, no biodegradable surfactant has been identified. Until an acceptable biodegradable surfactant is chosen, no definite impacts can be assessed.

TABLE 4-6
RELATIVE HAZARDS PRESENTED BY CANDIDATE HEAT EXCHANGER MATERIALS
Source: Phillips and Russo, 1978; HEW, 1979.

Metal	Toxicity to Humans From Oral Ingestion	Bioaccumulative Tendency			Human Hazard Rating
		Freshwater Fish Muscle	Marine Fish Muscle	Marine Shellfish or Crustaceans	
Titanium	Low	Low	Low	Low	Low
Aluminum	Low	High	Low	Low	Low
Stainless Steel					
Chromium	Low	Low	Low	Low	Low
Nickel	Low	Low	Low	Low	Low
Iron	Low	High	High	High	Low

4.3.3.6 Open-Cycle Plant Operation - Release of deaerated water from an open-cycle plant will not cause adverse effects, because rapid mixing of the discharge plume will increase oxygen concentrations to ambient levels before the end of the near-field (Sands, 1980). Release of higher-than-ambient salinity waters from open-cycle plants will not cause adverse environmental effects, because the difference in salinity between the discharge and ambient waters will not exceed 0.35 ppt (Appendix D).

4.3.4 Potential (Accidental) Effects

Operations in the marine environment present several unique hazards or potential for accidents. Collisions, extreme meteorological conditions, military action, political terrorism, or human error may cause catastrophic spills of OTEC working fluids and petroleum products stored aboard the platform. The effects of these releases during normal plant operation and during catastrophic events are described in the following subsections.

4.3.4.1 Working Fluid Release - OTEC heat exchangers will have extensive surface areas exposed to constant physical and chemical stresses. Leaks may develop in the heat exchangers or working fluid transport system, resulting in working fluid release. Toxicity data is only available for one of the candidate working fluids, ammonia, which is the most likely working fluid to be used in commercial OTEC plants. Natarajan (1970) reported ammonia concentrations of 55.0 to 71.1 mg liter^{-1} inhibited photosynthesis in unspecified marine phytoplankton. Toxicity studies on Sargassum shrimp *(Latreutes fucorum)* and filefish *(Monocanthus lispidus)* indicate that the lethal ammonia concentration for both species is approximately 1.0 mg liter^{-1} (Venkataramiah, 1979).

Ammonia release from heat exchanger leaks during normal OTEC operation is not expected to cause adverse environmental effects because low concentrations of ammonia stimulate primary productivity. Ammonia concentrations can only reach lethal levels in the event of a catastrophic spill (Appendix D). A catastrophic spill would kill zooplankton and fish stocks over a 63 km^2 area, resulting in a significant short-term environmental impact. A catastrophic spill from an ammonia-producing plantship would release up to 4.3×10^7 kg of ammonia, which could potentially affect a 428 km^2 area around the plantship (Appendix D).

4.3.4.2 Oil Releases - Oilspills from accidents at sea or petroleum leaks from minor spills may occur because of increased ship traffic resulting from OTEC operation. Oil releases could also occur during the deployment of the cold-water pipe. One proposed method for deploying the cold-water pipe consists of filling an insert within the pipe with 10,000 m^3 of oil for buoyancy and floating the pipe to the deployment site. The cold-water pipe would then be upended during deployment activities by pumping the oil out of the steel insert into a nearby barge or tanker (Moak et al., 1980). An accident during such an operation could cause total release of the oil, resulting in significant environmental impacts.

The toxic effects of petroleum product spills have been summarized by Cox (1977). The potential damages to marine organisms from oil pollution include:

- Coating and asphyxiation of organisms
- Contact poisoning of organisms
- Exposure to water-soluble toxic components of oil

A large oilspill could potentially affect the entire local environment and disrupt local populations of phytoplankton, zooplankton, nekton, marine mammals, and birds. A complete assessment of the effects of an oilspill resulting from OTEC activities cannot be provided until additional environmental and engineering information is available. However, careful consideration of the risk of potential accidents must accompany the design of OTEC plants to ensure that accidental oil releases will not create significant problems.

4.4 EFFECTS ON HUMAN ACTIVITIES

The major human activities in the OTEC resource area include commercial and recreational fishing, shipping and transportation, naval activities, scientific research, and recreation. The effects of commercial OTEC development on these activities are discussed in the following subsections.

4.4.1 Commercial and Recreational Fishing

Commercial and recreational fishing may be significantly affected by the siting and operation of OTEC plants. Fish attracted to OTEC plants will concentrate in the general vicinity of the plant, increasing the recreational yield of the area. However, the entrainment of egg and larval stages, the impingement of juvenile and adult fish stages, and the discharge of biocides may reduce the fish population downstream of the plant. These losses may be partially compensated by the redistribution of nutrients and resulting enhanced productivity. The net effect of OTEC operation on fishing depends on the biological productivity of the region. In highly productive regions

OTEC operation may slightly decrease the fishery resources, whereas in areas of low productivity, the net effect could benefit commercial and recreational fishing.

4.4.2 Shipping and Transportation

The effect of commercial OTEC development on shipping and transportation will be minimal because the sites will be designated for the production of baseload electricity or energy-intensive products, and should not interfere with commercial shipping. The location and boundaries of OTEC plants will be clearly marked on navigational charts and a Notice to Mariners issued by the U.S. Coast Guard. Shipping lanes may be established in areas having multiple OTEC plant deployments.

4.4.3 Naval Operations

U.S. Naval operations may occur in the vicinity of commercial OTEC plants; however, only minimal interference is expected. The Hydrographic Center of the Defense Mapping Agency is responsible for issuing a Notice to Mariners in the event of naval maneuvers or any other hazard to vessel operations. Submarine operation areas exist in the OTEC resource area and submarine traffic is a potential hazard to the cold-water pipe and mooring cables of OTEC plants. However, OTEC-use areas will be clearly marked on navigation charts. The military implications and applications of OTEC operation has been studied by Tracor, Inc., but the results are not available for public review.

4.4.4 Scientific Research

Commercial OTEC development will not have significant detrimental effects on scientific research activities. Deployment and operation of OTEC plants may stimulate scientific research through site evaluation and monitoring studies required for licensing.

4.4.5 Recreation

Recreational areas affected by commercial OTEC development are primarily concentrated in coastal regions. Most coastal states in which OTEC plants are likely to be located have Federally-approved coastal zone management programs, which will ensure that effects to recreational areas are mitigated.

4.4.6 Aesthetics

The analysis of aesthetic impact is complex, because a great variety of natural and man-made conditions exist in the OTEC resource area. OTEC development may have an adverse impact on aesthetics; the magnitude of the impact depends upon the nature and number of OTEC plants and their location. Degradation of aesthetics could decrease the public's enjoyment of beaches and coastal waters. This in turn may affect tourism, especially in highly-scenic areas. These effects should be assessed at the State and local level prior to deployment of OTEC plants.

4.5 INDIRECT EFFECTS

Indirect effects of commercial OTEC development may result from the manufacture of OTEC plants, alterations in existing resource demands, and increased demands on the communities where OTEC plants are developed. The nature and magnitude of these indirect impacts are dependent on the number and type of plants that will be built and characteristics of the construction site, deployment site, and transportation routes. The secondary environmental and socioeconomic effects of commercial OTEC development are discussed in the following subsections.

4.5.1 Secondary Environmental Effects

The development of OTEC as a commercial energy technology will have several indirect environmental effects. Modifications to existing shipyard facilities will be required for concrete platform designs (Table 4-7). Construction of a concrete OTEC plant would require deep graving docks and

protected shallow- and deep-water areas. Adequate graving docks are not presently available at U.S. shipyards. Puget Sound is the only U.S. port having adequate shallow- and deep-water protected areas (Table 4-7). Steel OTEC designs will require minimal modifications to existing shipyard facilities.

Impacts related to OTEC plant construction will be short-term and mitigated by controls imposed by existing Federal, State, and local regulations. For example, the placement of structures, such as piers and wharfs, will require Corps of Engineers approval and prior notification to the U.S. Coast Guard so that appropriate warnings to navigators can be issued. Any major construction or harbor modification will require an EIS, EA, or Finding of No Significant Impact, in accordance with the requirements of the National Environmental Policy Act (PL 91-190). Most of the coastal states in which construction facilities are likely to be located have Federally-approved coastal zone management programs which influence the design and impacts of facilities constructed along the coast. These measures will minimize the impact of harbor and shipyard modifications required for the manufacture of OTEC plants and will ensure that unacceptable environmental impacts do not occur.

Ship traffic will increase in the vicinity of OTEC sites as a result of OTEC plant deployment, operation, and the transport of products manufactured on plantships. Increased ship traffic could interfere with commercial fishing vessels, recreational boating, and commercial vessels not associated with the OTEC plant. Atmospheric emissions and landscape alterations will result from mining and smelting of mineral ores for OTEC plant components; the associated impacts cannot be accurately predicted without specific information on material requirements.

4.5.2 Socioeconomic Effects

In general, the island communities of the United States suitable for OTEC development are almost totally dependent upon imported oil, with few viable alternatives available (Sullivan et al., 1980). Thus, these island

TABLE 4-7. U.S. PORTS WITH SUITABLE FACILITIES FOR OTEC PLATFORM CONSTRUCTION.
Source: Modified from Delta Marine Consultants, 1980.

Platform Type (Fig. 1-2)	Hull Material**	Adequate Access Channel	Initial Construction	Secondary Construction	
			Graving Dock	Protected Shallow Water Site	Protected Deep Water Site
Concrete ship (external heat exchanger)	nwc	Puget Sound, WA Corpus Christi, TX*	None	Puget Sound, WA	Not Required
	lwc	Puget Sound, WA Long Beach, CA San Francisco, CA Corpus Christi, TX* Galveston, TX* Hampton Roads, VA*	None	Puget Sound, WA	Not Required
Concrete ship (external heat exchangers, upside down construction)	nwc	Puget Sound, WA Long Beach, CA San Francisco, CA Corpus Christi, TX* Galveston, TX* Baltimore, MD* Hampton Roads, VA*	None	Puget Sound, WA	Not Required
	lwc	11 sites on East Coast 9 sites on Gulf Coast 8 sites on West Coast Hawaii Puerto Rico	None	Puget Sound, WA	Not Required
Concrete spar (external heat exchanger)	nwc	Puget Sound, WA Long Beach, CA San Francisco, CA Corpus Christi, TX Galveston, TX* Hampton Roads, VA*	None	Puget Sound, WA	Puget Sound, WA
	lwc	11 sites on East Coast 9 sites on Gulf Coast 8 sites on West Coast Hawaii Puerto Rico	None	Puget Sound, WA	Puget Sound, WA
Concrete spar (internal heat exhanger)	nwc	Puget Sound, WA	None	Not Required	None
	lwc	Puget Sound, WA Corpus Christi, TX* Galveston, TX*	None	Not Required	Puget Sound, WA
Steel ship (external and internal heat exchanger)	Steel	Available at all U.S. ports with adequate construction facilities.	San Diego, CA San Francisco, CA Tampa, FL New Orleans, LA+ Quincy, MA Baltimore, MD+ Pascagoula, MS+ Brooklyn, NY Chester, PA+ Newport News, VA Norfolk, VA+ Portland, OR Sparrows Point, MD San Francisco, CA+	Puget Sound, WA Long Beach, CA San Francisco, CA Corpus Christi, TX* Galveston, TX* Baltimore, VA* Hampton Roads, VA Grays Harbor, WA* Freeport, TX* New York, NY Port Everglades, FL Puerto Rico*	Not Required

*Proposed
**nwc: normal weight concrete; lwc: light weight concrete
+Adequate floating dock available.

communities are highly vulnerable to oil price increases and future oil embargoes. Commercial OTEC development will have a positive influence on island economies by initiating a process for obtaining total energy independence, thereby creating long-term price stability for economic development.

OTEC plant components will be manufactured at shipyards and industrial facilities in island communities and the continental United States. The manufacture and assembly of OTEC plants, and the modification of existing harbors and shipyard facilities will result in the creation of construction-related jobs. The projected job impact of OTEC plant construction will be significant for large depressed city areas, where most shipyards are located. Approximately 2,000 worker-years of shipyard employment would be required to construct a 40-MWe plantship (Francis et al., 1979).

Operation and support of OTEC plants will create additional employment opportunities. Estimates indicate that approximately 20 to 30 persons would be required to operate a commercial OTEC plant (Moak et al., 1980), and an additional number of people would be employed in a support capacity. Jobs provided by commercial OTEC development would most likely replace any jobs lost at facilities powered by fossil fuels.

There may be significant short-term impacts to the population characteristics of communities near OTEC plant assembly sites, depending on the characteristics of the site and the local community infrastructure. Temporary housing and community services (water, electricity, sewage) may be needed for construction crews. Population impacts would probably be reduced to minimal levels after the construction of an OTEC plant is complete and operation begins.

4.6 CUMULATIVE ENVIRONMENTAL EFFECTS

Effects of OTEC development may include (1) habitat disruption, (2) attraction to the platform, (3) toxic effects from biocide release, working fluid spills, and other discharges, (4) redistribution of food

resources from platform attraction, impingement, entrainment, and nutrient redistribution, (5) changes in ocean water properties, and (6) human activity alterations. Marine organisms may be affected either directly or indirectly by these effects and by synergistic interactions between these effects. Nekton populations will increase in the vicinity of the plant because of attraction to structure and lights, but could decrease in downstream areas as a result of entrainment of eggs and larval stages and impingement of juvenile and adult stages. Plankton populations will be reduced immediately downstream of OTEC plants as a result of entrainment and biocide release; however, the redistribution of nutrient-rich deep water into the photic zone may stimulate plankton productivity and ultimately increase plankton and nekton populations. Benthic community effects will center primarily on their planktonic larval stages, which may be reduced as a result of entrainment and biocide release. Impacting the egg and larval stages of benthic organisms has the potential of reducing recruitment stocks and adult benthic populations downstream of the plant.

The size of the area influenced by OTEC operations will be determined by the size of the plant and the spacing distance between plants. Decreasing interplant distance will increase the magnitude of plant operational effects, while reducing the geographic region affected. In addition, clustering of plants may synergistically increase the magnitude of environmental effects associated with multiple plant operations.

In general, OTEC operation will affect nearshore environments to a greater degree than offshore environments because:

- The coastal zone is highly biologically-productive and used as spawning, breeding, and calving grounds for many species of marine organisms; therefore, disturbances in nearshore regions are likely to affect commercially-important and ecologically-sensitive areas.

- Nearshore populations rely on local recruitment from life stages concentrated in small areas and can be severely disrupted by localized impacts.

- The nearshore has less horizontal homogeneity than the offshore environment, which limits the ability of nearshore organisms to move away from disturbances without leaving their preferred environment.

The cumulative effect of commercial OTEC development may significantly affect threatened and endangered species. Specific plant locations are required to predict the potential cumulative effect of commercial OTEC development on threatened and endangered species. OTEC development near island communities may impact threatened and endangered species which are endemic to the area, or affect species which migrate to the area for reproductive or feeding purposes. These species inhabit or make use of nearshore areas around islands, and OTEC plants would be sited either on land or close to shore. Migratory threatened and endangered species could abandon areas impacted by OTEC operation; however, this could disrupt their breeding, calving, or feeding activities. Endemic threatened and endangered species could be directly affected if their habitat is disrupted by OTEC development. To avoid or mitigate impacts to threatened and endangered species, plant siting should avoid critical habitats and ecologically-sensitive areas of threatened and endangered species.

OTEC development in oceanic regions of the Gulf of Mexico, Pacific Ocean, and Atlantic Ocean is not expected to significantly affect threatened and endangered species. Plants will be located far offshore, where threatened and endangered species are highly motile and have worldwide distributions. Thus, oceanic threatened and endangered species should be able to avoid any localized impacts associated with OTEC operation.

Commercial OTEC development in climatically-sensitive areas may alter weather patterns as a result of sea-surface temperature changes and carbon dioxide release. The magnitude and nature of climatic effects resulting from commercial OTEC development have not been ascertained; additional research is required.

4.7 UNAVOIDABLE ADVERSE EFFECTS AND MITIGATING MEASURES

Preliminary estimates demonstrate that single and multiple deployments of 40-, 100-, and 400-MWe OTEC plants have the potential for significantly impacting marine and terrestrial environments through unavoidable adverse effects associated with their siting, construction, and operation. The identified unavoidable effects associated with commercial OTEC development include:

- Biota attraction and avoidance
- Entrainment of planktonic organisms, particularly larvae
- Impingement of ecologically- or commercially-important species
- Biocide release
- Ocean water redistribution, particularly nutrient redistribution and sea-surface temperature alterations

The potential for, and magnitude of, environmental impacts resulting from these OTEC development issues can be mitigated or reduced by implementing various siting and design considerations (Table 4-8). In general, these measures are related to platform siting, and intake and discharge structure design. The following subsections evaluate the effectiveness of these mitigating measures.

4.7.1 Platform Siting

Siting is the single-most important determinant of the potential for environmental impact. Platform siting will determine the magnitude of environmental impacts related to OTEC activities, because the local populations define the ecological sensitivity of an area. For instance, areas of low ecological or commercial importance are less likely to experience significant impact from OTEC development than areas of high

TABLE 4-8. POTENTIALLY ADVERSE ENVIRONMENTAL IMPACTS AND MITIGATING MEASURES

Issue	Community Affected					Mitigating Measures (Ranked by Effectiveness)	Research Needs
	Plankton	Nekton	Benthos	Threatened and Endangered Species	Man's Activities		
Biota Attraction and Avoidance	Increased number of organisms due to attraction to lights.	Increased number organisms due to attraction to structure and lights.	Colonization of exposed structures.	Possible avoidance of area due to human presence and noise.	-Increased fishing. -Loss of desired faunal diversity.	-Site away from breeding and nursery grounds. -Reduce lights and noise to minimum needed for safe operation. -Reduce attraction surfaces.	-Site evaluation studies to determine ecological sensitivity of areas. -Determine biota attraction and avoidance to different platform configurations and lighting systems.
Organism Entrainment	Reduction in population size.	-Reduction in population size due to mortality of eggs and larvae. -Potential reduction in food resources.	Reduction in population size due to mortality of planktonic larval stages.	Possible reduction in food resources.	Potential decrease in fishery resources.	-Site intakes away from ecologically-sensitive areas. -Site intakes at depths that will entrain the least number of organisms. -Reduction in through-plant shear forces.	-Site evaluation studies to determine ecological sensitivity of area. -Determine vertical distribution of local populations. -Entrainment mortality studies that determine plant induced mortality.
Organism Impingement	None.	Reduction in population size due to mortality of juveniles and adults.	None.	None.	Potential reduction in fishery resources.	-Use velocity caps to achieve horizontal flow fields. -Use fish return system. -Site intakes at depths that will impinge the least number of organisms. -Reduce intake velocities.	-Site evaluation studies to determine ecological sensitivity of area, and size, structure, and vertical distribution of fish populations. -Impingement mortality prevention studies.

Table 4-8. Potentially Adverse Environmental Impacts and Mitigating Measures (Continued)

Issue	Community Affected					Mitigating Measures (Ranked by Effectiveness)	Research Needs
	Plankton	Nekton	Benthos	Threatened and Endangered Species	Man's Activities		
Biocide Release	Reduction in population size.	-Decreased metabolic activity and plume avoidance by adults. -Reduction in population size due to mortality of eggs and larvae.	-Reduction in population size due to mortality of planktonic larval stages. -Chronic or acute effects on adults.	-Possible avoidance of plume. -Possible reduction of food resource.	-Potential reduction of fishery resources. -Decreased aesthetics.	-Discharge below photic zone. -Use alternate methods for biofouling control. -Rapid dilution through use of diffusers. -Site specific biocide release schedule and concentration. -Site discharges away from ecologically-sensitive areas.	-Site evaluation studies to determine ecological sensitivity of area. -Acute and chronic toxicity and bioassay studies on representative organisms.
Nutrient Redistribution	Increased productivity.	Potentially increased food resource.	Potentially increased food resource.	Potentially increased food resource.	-Potential increase in fishery resource. -Potentially decreased aesthetics.	Discharge into photic zone. Discharge below photic zone.	Determine discharge plume stabilization depth and downstream mixing rate so that physical models can be calibrated.
Sea-Surface Temperature Alterations	None.	None.	None.	None.	Potential climatic alterations.	Discharge below the thermocline.	Monitor temperature-density profiles from OTEC discharges to calibrate predictions.

ecological or commercial value. Siting away from ecologically-sensitive areas (such as coral reefs, seagrass beds, reproductive areas, and critical habitats for threatened or endangered species) and important fishery-resource areas is the most effective and fundamental means available for minimizing significant adverse impacts. Avoidance of OTEC plants by organisms sensitive to human activities can be minimized by reducing light and noise levels on OTEC platforms to the minimum required for safe operation.

4.7.2 Intake Considerations

Unavoidable adverse effects associated with the withdrawal of resource waters by OTEC plants include organism entrainment and impingement. Entrainment of planktonic organisms and the larvae of oceanic and nearshore organisms may reduce the food resource for higher trophic levels, and reduce adult fish and benthic invertebrate populations downstream of the plant. Impingement of juvenile and adult organisms may also reduce the food resource for higher trophic levels and reduce existing and future population sizes. Both entrainment and impingement effects have the potential for adversely affecting the fishery resources in the OTEC resource area.

The design of OTEC intake structures will determine, in part, the number of organisms withdrawn and the associated mortality rate. Impingement and entrainment may be reduced by taking advantage of the natural vertical stratification of marine organisms and locating the intakes at depths with low organism concentra- tions. Entrainment mortality may be effectively reduced by minimizing the physical abuse to which entrained organisms are subjected during passage through the plant. Low intake velocities will minimize shear and acceleration stresses, and the number of pipe bends and constrictions could be reduced to minimize abrasion and impaction of entrained organisms.

Conventional power plants use various intake designs and technology considerations for reducing organism impingement rates. Similar design considerations should be made for commercial OTEC plants. OTEC intakes should be engineered to attract the least number of organisms possible, either

through structure design, such as screening the water prior to entry into a land-based plant's warm-water intake, or the placing intakes as far as possible from structures that attract organisms. Fish sense and avoid horizontal flow fields more readily than vertical flow fields; therefore, commercial OTEC plants may impinge fewer organisms if the resource water is withdrawn horizontally rather than vertically, either through intake orientation or the use of a velocity cap (Hansen, 1978). Reducing intake flow velocities to a point at which most fish, squid, and shrimp could escape withdrawal may further reduce organism impingement rates. Fish-return systems could also be used to reduce impingement losses.

4.7.3 Discharge Considerations

Significant environmental effects resulting from the discharge of warm and cold water by OTEC plants include organism mortality from biocide release, increased productivity from the upwelling of nutrient-rich waters, and sea-surface temperature alterations from ocean water redistribution. The magnitude of these environmental effects will be determined by the discharge plume's dilution rate and stabilization depth (Sullivan and Sands, 1980b).

Plume behavior can be controlled through discharge structure design. Plume temperature and density, discharge orientation, discharge velocity, discharge depth and the number of discharge ports or diffusers can all be modified to produce desired plume behavior (Sullivan and Sands, 1980b). Mixing cold and warm discharges will result in a plume density between that of warm- and cold-water discharges and cause the mixed plume to stabilize deeper than warm-water plumes and shallower than cold-water plumes. The plume from a discharge structure oriented vertically downward tends to stabilize deeper than the plume from a horizontal discharge, due to the initial downward momentum and the entrainment of denser deep water. High discharge velocities tend to increase turbulence in the plume, increasing mixing and dilution rates. The plume stabilization depth is influenced by the discharge depth, and the number of discharge ports affects plume dilution rates.

Plume stabilization below the photic zone will reduce the potential for adverse impacts, decrease the potential of degrading the warm-water resource downstream of the plant, and minimize sea-surface temperature alterations. The most effective means for reducing the adverse effects of OTEC effluent discharges is to employ biofouling control methods which do not require the release of biocides. If biocide release is necessary to maintain heat exchanger efficiency, designing the discharge structure to allow the discharge plume to dilute rapidly and stabilize below the photic zone will reduce environmental effects because:

- Phytoplankton, the organisms most sensitive to biocides, are limited to depths receiving sufficient light for photosynthesis, and would, therefore, not be affected.

- Chlorine degradation to potentially toxic organic compounds is slower below the photic zone, allowing greater plume dilutions before formation of the compounds.

- Depths below the photic zone have far fewer organisms, commercially-important species, and ecologically-important groups than do photic zone waters.

Discharging the effluent below the photic zone, however, also decreases the potential for an increase in primary productivity that could result from the release of nutrients into the photic zone. The benefits and advantages of various discharge plume behaviors should be weighed on a site-by-site basis to select the alternative with the least adverse impact.

4.8 RELATIONSHIP BETWEEN SHORT-TERM USE OF THE ENVIRONMENT AND MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

The proposed action in this EIS, the encouragement of commercial OTEC development, is not a short-term use of the environment. Rather, it is a long-term commitment to an energy technology which could assist im promoting energy self-sufficiency for the United States. Commercial OTEC development

will primarily occur in tropical-subtropical communities which have an adequate thermal resource and require a renewable, unlimited energy source which is free from foreign control. Commercial OTEC plants may cause environmental disturbances in the vicinity of deployment and operation sites, but careful consideration of the environmental characteristics at candidate OTEC sites during the design of OTEC plants will reduce the magnitude of environmental impacts to acceptable levels and maintain the long-term productivity of the region.

4.9 IRREVERSIBLE AND IRRETRIEVABLE RESOURCE COMMITMENT

Resources that would be irreversibly or irretrievably committed upon implementation of the proposed action include:

- Raw materials used in the construction of commercial OTEC plants.

- Energy in the form of fuel required for construction, transportation, operation, and maintenance of OTEC plants.

- Plant constituents, such as trace metals and chemical biocides, released during normal plant operation because technology is not adequate to recover them efficiently.

- Use of the deployment site for other purposes, and commitment of nearby areas for plant access.

- Flora and fauna impacted by OTEC development, which may affect commercial resources of localized areas.

Chapter 5

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The preparation of the EIS was a joint effort employing members of the scientific and technical staff of Interstate Electronics Corporation (IEC) and the Office of Ocean Minerals and Energy (OME) of the National Oceanic and Atmospheric Administration (NOAA). Technical advice was provided by consultants selected by IEC. The preparers of the EIS and the sections for which they were responsible are presented in Table 5-1.

TABLE 5-1

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Chapter 6

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In compliance with the National Environmental Policy Act of 1969, NOAA developed an Environmental Issues Discussion Document and held a public scoping meeting prior to preparing this Environmental Impact Statement (EIS) on Commercial OTEC Development. The public scoping meeting was held 30 October 1980 in Washington, D.C., to determine the scope of issues to be addressed in the EIS, and to identify the significant issues related to establishing a legal regime for the commercial development of OTEC. Notice of the scoping meeting and the availability of the discussion paper was published on pages 63543 and 63544 of the Federal Register, September 25, 1980. Attendees of this meeting included representatives of Federal, State, and local agencies, private industry, academic institutions, special interest groups, and members of the general public.

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Honolulu, Hawaii 96813

Chapter 7

GLOSSARY, ABBREVIATIONS, AND REFERENCES

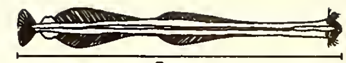
Glossary

ABUNDANCE	Relative degree of plentifulness.
ACUTE EFFECT	The death or incapacitation of an organism caused by an action or a substance within a short time (normally 96 hours).
ADVECTION	The process of transport of water or of an aqueous property solely by the mass motion of the the oceans, most typically via horizontal currents.
AESTHETICS	Pertaining to the natural beauty or attractiveness of an object or location.
AIR BUBBLE SCREEN	A barrier of air bubbles designed to impede the passage of fish.
ALUMINA	Aluminum oxide (Al_2O_3). Intermediate material in the production of aluminum from bauxite.
AMBIENT	Pertaining to the existing conditions of the surrounding environment.
AMERTAP-BALL	A slightly oversized foam rubber ball that is used to clean heat exchanger surfaces. Such balls are continually circulated through heat exchanger tubes to remove slime and fouling layers.
ANTIFOULING COATING	A special paint containing a toxic substance, such as copper, used on ship hulls to prevent marine organisms from attaching themselves.
AREA OF PARTICULAR CONCERN (APC)	A coastal resource area subject to serious or potential use conflicts. Established under considerations outlined in 15 CFR 923.21 (d).
ARTICULATING TOWER	A tower constructed with one or more flexible joints to absorb stress.

ASSEMBLAGE	A group of organisms having a common habitat.
ASSIMILATION	The conversion of nonliving matter into tissue by living organisms.
ATMOSPHERE	A unit of pressure equal to the air pressure at mean sea level, comparable to a 760-mm column of mercury.
AUTOIGNITION TEMPERATURE	The temperature at which ignition can occur spontaneously.
BACKGROUND LEVEL	The naturally occurring concentration of a substance within an environment that has not been affected by unnatural additions of that substance.
BALEEN WHALE	A whale of the suborder Mysticeti, which feeds using whalebone (baleen) to strain plankton.
BAR SCREEN	A screen constructed of heavy gauge bars to prevent passage of large objects.
BASELINE SURVEYS AND BASELINE DATA	Surveys and the data collected before the initiation of actions that may alter an existing environment.
BATHYMETRY	The measurement of ocean depths to determine the sea floor topography.
BATHYMETRIC GRADIENT	The rate of change of depth in a body of water.
BATHYPELAGIC ZONE	The biogeographic realm of the ocean lying between depths of 1,000 and 4,000 m.
BENTHOS	All marine organisms living on or in the bottom of the sea.
BENTHIC COMMUNITY	A community of organisms living on or in the bottom of the sea.
BILLFISH	A fish, such as a marlin, with long slender jaws.
BIOACCUMULATION	The uptake and assimilation of substances, such as heavy metals, leading to a concentration of these substances within organism tissues.
BIOCIDE	A substance capable of destroying living organisms.
BIODEGRADABLE	Capable of being broken down especially into innocuous products, by the action of living organisms, such as microorganisms.
BIOFOULING	The adhesion of various marine organisms to underwater structures.

BIOTA	Collectively, the plants and animals of a region.
BIOTIC	Pertaining to life and living organisms.
BIOTIC GROUPS	Organisms that are ecologically, structurally, or taxonomically grouped.
BIOMASS	The weight of living matter, including stored food, present in a population, expressed in terms of a given area or volume of water or habitat.
BLOOM	A relatively high concentration of phytoplankton in a body of water, resulting from rapid proliferation during a time of favorable growing conditions generated by nutrient and sunlight availability.
BOTTOM-RESTING TOWER	An OTEC plant design in which the plant is placed on a tower that rests on the ocean bottom at a depth of 300 m or less.
BREEDING GROUND	An area used by animals to produce or bring forth their young.
BRITISH THERMAL UNIT (BTU)	A unit of heat energy that is equal to 2.93×10^{-4} kWh.
CANDIDATE SITES	Specific areas being considered for OTEC deployment.
CARANGID	Any of the large Carangidae family of marine spiny-finned fishes. Includes important food fishes such as jacks, pompanoes, and yellowtail.
CARBON FIXATION	Process by which primary producers (phytoplankton) absorb inorganic carbon for production of energy during photosynthesis.
CARNIVOROUS	Subsiding or feeding on animal tissues.
CENTERLINE DILUTION	Dilution that occurs along the center of a plume.
CENTIGRADE DEGREE	Unit of thermometric scale on which the interval between the freezing point and boiling point of water is divided into 100 degrees with 0° representing the freezing point and 100° the boiling point; also called Celsius degree.

CHAETOGNATH — A phylum of small planktonic, transparent, worm-like invertebrates also known as arrow-worms; they are often used as water-mass tracers.



CHLOROPHYLL — A group of green plant pigments that function as photoreceptors of light energy for photosynthesis.

CHLOROPHYLL _a_ — A pigment used in photosynthesis that serves as a convenient measure of phytoplankton biomass.

CHRONIC EFFECT — A sublethal effect of a substance on an organism which reduces the survivorship of that organism after a long period of exposure to the substance.

CLOSED-CYCLE SYSTEM — An OTEC power cycle in which the working fluid does not enter or leave the system but is continuously recycled.

CLUPEID — Any of the large family Clupeidae of soft-finned bony fishes having a laterally compressed body and a forked tail, such as herring and pilchard.

COASTAL ZONE — The region, which extends seaward and inland from the shoreline, and that is significantly influenced by both marine and terrestrial processes.

COLD-WATER PIPE — That component of the OTEC plant through which cold water is drawn, it extends to about 1000 m depth.

COMPENSATION DEPTH — The depth at which oxygen production by photosynthesis equals that consumed by phytoplankton respiration during a 24-hour period.

CONDENSER — The portion of a heat exchanger that conducts heat from the gaseous working fluid to the cold water system. In this process the vapor is changed, or condensed, from a gas to a liquid.

CONDUIT — A channel through which a material is transported.

CONTIGUOUS ZONE — An area of the high seas adjacent to a State's territorial sea, in which the State may exercise the control necessary to prevent infringement of the customs, fiscal, immigration, or sanitary regulations within its territory or territorial sea. This zone extends 12 nmi from the baseline from which the territorial sea is measured. The zone is part of the high

seas, and the Coastal State exercises no sovereignty over these waters other than to the extent covered by the Convention on the Territorial Sea and the Contiguous Zone.

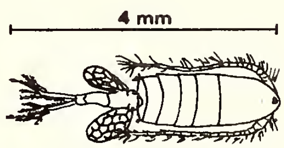
CONTINENTAL MARGIN — The zone separating the emergent continents from the deep sea floor; generally consists of the Continental Shelf, Continental Slope, and Continental Rise.

CONTINENTAL RISE — A gentle slope with a generally smooth surface between the Continental Slope and the deep ocean floor.

CONTINENTAL SHELF — That part of the Continental Margin adjacent to a continent extending from the low water line to a depth, generally 200 m, where the Continental Shelf and the Continental Slope join.

CONTINENTAL SLOPE — That part of the Continental Margin consisting of the declivity from the edge of the Continental Shelf down to the Continental Rise.

COPEPODS — A large diverse group of small planktonic crustaceans, mostly between 0.5 and 10 mm in length, representing an important link in marine food chains.



CORROSION — The gradual erosion of a surface, especially by chemical means.

CRITICAL-TEMPERATURE PRESSURE — The vapor pressure of a substance when the liquid and gas phases are in equilibrium.

CRUSTACEANS — Animals with jointed appendages and a segmented external skeleton composed of a hard shell. The group includes barnacles, crabs, shrimps, and lobsters.

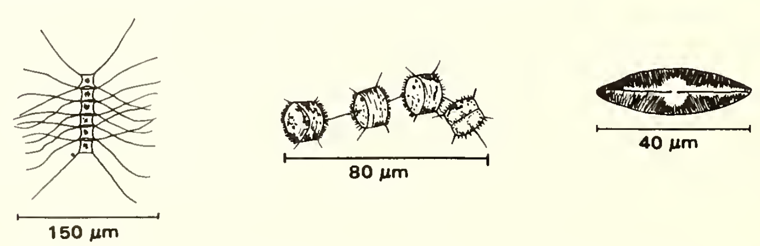
CRYOLITE — A mineral, Na_3AlF_6, used in the reduction of aluminum ore.

CUMULATIVE IMPACT — Impact resulting from the additive effect of individually harmless or less harmful factors.

CURRENT DRAG — Resistance caused by the friction of a fluid moving past a stationary body.

CURRENT SHEAR — The measure of the rate of change of current velocity with distance. A shear force caused by current action, see SHEAR FORCE.

DECIBEL (db)	In the measurement of sound intensity, a unit for describing the ratio of two intensities, or the ratio of an intensity to a reference intensity.
DECOMPOSER	An organism, such as bacteria, which converts the bodies or excreta of other organisms into simpler substances.
DEEP SOUND CHANNEL	A region in the water column in which sound velocity reaches a minimum value. Above this region, sound rays are bent downward, below it, they are bent upward; the sound rays are consequently channeled into this region. Sound traveling in this channel can be detected thousands of miles from the sound source.
DELTA t	Difference in temperature between ocean depths.
DEMERSAL	Living on or near the bottom of the sea.
DENSITY	The mass per unit volume of a substance.
DESALINATION	The process of removing salts from seawater.
DIATOMS	Microscopic phytoplankton characterized by a cell wall of overlapping silica plates. Populations in the water column and in sediments vary widely in response to changes in environmental conditions.



DIEL CYCLE	Pertaining to, or occurring within, a 24-hour cycle.
DIEL MIGRATION	The cyclical pattern of vertical migration that occurs within a 24-hour period. Usually, organisms that display this pattern migrate toward the surface during the night and away from the surface during the day.
DIFFUSER	The section of discharge pipe that is modified, usually through the addition of numerous ports or holes, to promote rapid mixing of the discharge with the ambient waters.

DIFFUSION — Transfer of material (e.g. salt) or a property (e.g. temperature) by eddies or molecular movement. Diffusion causes dissemination of matter under the influence of a concentration gradient, with movement from the stronger to the weaker solution.

DILUTION — A reduction in concentration through the addition of ambient waters. Expressed as the ratio of the sum of the volumes of ambient water plus plume water to the volume of plume water. A dilution of 5 indicates

$$\frac{\text{4 parts ambient water + 1 part plume water}}{\text{1 part plume water}}$$

DINOFLAGELLATES — A large diverse group of phytoplankton with whip-like appendages, with or without a rigid outer shell, some of which feed on particulate matter. Some members of this group are responsible for toxic red-tides.

DISCHARGE FIELD — An area of the water column into which a fluid is discharged.

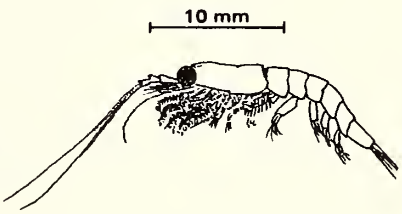
DISCHARGE PLUME — The fluid volume, released from the discharge pipe, which is distinguishable from the surrounding water.

DISCHARGE PORT — The opening through which fluid is released to the environment.

DISPERSION — Dissemination of discharged water over large areas by the natural processes of ocean turbulence and ocean advection.

DISSOLVED OXYGEN — The quantity of oxygen (expressed in mg liter^{-1}, ml liter^{-1}, or parts per million) dissolved in a unit volume of water. Dissolved oxygen is a key parameter in the assessment of water quality.

DIVERSITY	A measure of the variety of species in a community that takes into account the relative abundance of each species.
DOLPHIN	Either of two active pelagic food fishes of the genus *Coryphaena* (suborder Percoidea) of tropical and temperature seas. Any of various small toothed whales of the family Delphinidae.
DOWNWELLING	A downward movement of water generally caused by converging currents or the higher density of a water mass relative to the surrounding water.
DRY WEIGHT	The weight of a sample of material or organisms after all water has been removed; a measure of biomass when applied to organisms.
ECOSYSTEM	An ecological community considered as a unit together with its physical environment.
EDDY	A circular mass of water within a larger water mass that is usually formed where currents pass obstructions, where two adjacent currents flow counter to each other, or along the edge of a permanent current. An eddy has a certain integrity and life history, circulating and drawing energy from a flow of larger scale.
EFFLUENT	In this case, a liquid discharged from an OTEC plant that has thermal or chemical properties that differ from the ambient water.
EFFLUX	An action or process of flowing out; effluent.
ELECTRICAL GRID	Network of conductors for distribution of electric power.
ELECTROLYSIS	The process of chemical changes effected by passage of an electric current through a nonmetallic electric conductor.
ELECTROLYTIC REDUCTION	Reduction through electrolysis.

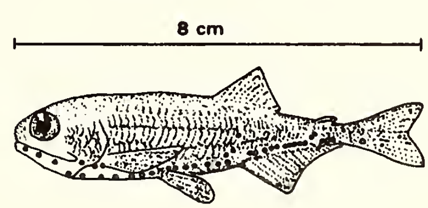
ENDANGERED SPECIES	Any species which is in danger of extinction throughout all or a significant portion of its range other than a species of the class Insecta determined by the Secretary of the Interior to constitute a pest whose protection under the Endangered Species Act would present an overwhelming and overriding risk to man. (Endangered Species Act of 1973, PL 93-205).
ENHANCED HEAT EXCHANGER	Heat exchanger with increased surface area, either by addition of fins or surface coating.
ENDEMIC	Restricted or peculiar to a locality or region.
ENERGY INTENSIVE PRODUCTS	Material, such as aluminum and ammonia, which requires large amounts of energy to produce.
ENTRAINMENT	The process by which organisms are drawn into the intake pipes of an OTEC plant; the process by which ambient waters are mixed with the discharge plume.
EPIPELAGIC	Of, or pertaining to that portion of the oceanic zone extending from the surface to a depth of about 200m.
EUPHAUSIID	Shrimp-like, planktonic crustaceans which are widely distributed in oceanic and coastal waters, especially in cold waters. These organisms, also known as krill, are an important link in the oceanic food chain. 
EVAPORATOR	The chamber in which the working fluid is vaporized prior to passing through the turbine.
EXCLUSIVE ECONOMIC ZONE (EEZ)	An area, established by the Third United Nations Conference on the Law of the Sea, which extends seaward to a distance of 200 nmi from the baseline from which the breadth of the territorial sea is measured, in which the bordering country has exclusive rights to the natural resources of the seabed and the subsoil of the continental shelf. The EEZ has not been adopted by the U.S. Congress.
FACILITY	A structure that is built, installed, or established to serve a particular service (e.g. an electricity generating facility).

FAR FIELD	The region where natural ocean processes become the dominant factors in the mixing of discharge waters.
FAUNA	The animal population of a particular location, region, or period.
FEDERAL ACTION	Actions which include: (1) recommendations on legislation by Federal agencies, (2) projects and activities directly undertaken, supported or otherwise approved by Federal agencies, and (3) the establishment or modification of Federal regulations, rules, procedures, and policy. Fully defined in 40 CFR 1500.5.
FILE FISH	Fish of the order Plectognathi with rough granular leathery skins (genera *Aluterus*, *Cantherhines*, and *Monacanthus*).
FIN WHALE	A whale of the suborder Mysticeti, genus *Balaenoptera physalus*.
FLAGELLATE	An organism with one or more whip-like locomotory organelles. A protozoan of the class Mastigophora.
FLASH POINT	The lowest temperature at which vapors from a volatile liquid will ignite upon the application of a small flame.
FLOATING DOCK	A form of dry dock which can be partially submerged by controlled flooding to receive a vessel, then raised by pumping out water so that the vessel's bottom can be exposed.
FLORA	The plant population of a particular location, region, or period.
FLOW FIELD	The velocity and density of a fluid as functions of distance and time.
FOOD CHAIN	A group of organisms involved in the transfer of energy from its primary source to herbivores and finally to carnivores and decomposers.
FOOD WEB	A complex pattern of several interlocking food chains in a complex community, or between several communities.
FOSSIL FUELS	Fuel ultimately derived from living organisms of a past geologic age.

FRACTIONAL DISTILLATION	The process of separating components of a mixture through differences in physical or chemical properties.
GALVANIC CORROSION	The corrosion, above normal corrosion of a metal, associated with the flow of electric current to a less active metal in the same solution and in contact with the more active metal.
GELATINOUS ORGANISMS	Generally, the large organisms composed of a jellylike substance, including the cnidarians, salps, and ctenophores.
GENERIC	Relating to, or characteristic of, a whole group or class.
GEOLOGICAL HAZARDS	A geologic condition that poses a potential danger to life and property, such as earthquake, mudflow, or faulting.
GIGAWATT ELECTRIC (GWe)	One billion (10^9) watts, or 1,000 MWe, of electric power.
GRADIENT	The change in value of a quantity with change in a given variable, such as distance (e.g. change in temperature with depth).
GRAVING DOCK	A form of dry dock, consisting of an artificial basin fitted with a gate, into which a vessel can be floated and water pumped out to expose the vessel's bottom.
GRAZING	The feeding of zooplankton upon phytoplankton. In relation to OTEC, refers to plantships that travel through an area to exploit optimum thermal resources.
GREENHOUSE EFFECT	Warming of the earth's surface and lower layers of the atmosphere that tends to increase with increasing atmospheric carbon dioxide and is caused by the selective transmission, reradiation, and absorption of solar radiation.
GROUND CREEP	A slow, more or less continuous, downward and outward movement of slope-forming soil or rock; slow deformation resulting from long application of a stress.
GUY	A rope, chain, or rod attached to something as a brace.
GUYED TOWERS	A tower supported by a guy.
HABITAT	A place or type of site where an organism normally lives or where individuals of a population live.
HAZARDOUS SUBSTANCE	A substance listed by the EPA in the Clean Water Act as a hazardous substance (Section 311(b) (2)).

HEAT EXCHANGER	A material (usually metal) with a high coefficient of thermal conductivity which is used to exchange heat between the working fluid and the heat source or sink.
HEAVY METALS OR ELEMENTS	Elements that possess a specific gravity of 5.0 or greater.
HERBIVOROUS	Feeding or subsisting principally or entirely on plants or plant products.
HERTZ (Hz)	A unit of frequency equal to one cycle per second.
HIGH SEAS	The open sea beyond and adjacent to the territorial sea, which is subject to the exclusive jurisdiction of no one nation. May include the contiguous zone. Also an informally defined oceanic region, see OCEANIC.
HOLOPLANKTON	Organisms that spend their complete life cycle as plankton.
HUMAN ENVIRONMENT	All the factors, forces, or conditions that affect or influence the growth and development or the life of humans.
HURRICANE	A cyclonic storm, usually of tropical origin, covering an extensive area and containing winds of 120 kilometers per hour or greater.
HYDRAULIC TURBINE	A rotary engine actuated by the impulse of a current of water.
HYPOBROMOUS ACID	An acid, HOBr, which forms very quickly upon the addition of chlorine to seawater.
ICHTHYOPLANKTON	Fish eggs and weakly motile fish larvae.
IMPINGEMENT	A situation in which an organism is forced against a barrier, such as an intake screen, as a result of the intake of water into a facility such as a powerplant.
INDIGENOUS	Having originated in and being produced, growing, or living naturally in a particular region or environment.
INITIAL MIXING	The dispersion or diffusion of liquid, suspended-particulate, and solid phases of a material, which occurs immediately after relase. This type of mixing occurs in the near-field zone.
INORGANIC COMPOUNDS	Compounds not containing carbon.

IN SITU	In the natural or original position; pertaining to samples taken directly from the environment in which they occur.
INVERTEBRATES	Animals without backbones.
ION	An electrically charged group of atoms, either negative or positive.
JET	A forceful stream of liquid or gas discharged from a narrow opening.
JUVENILE	A young individual resembling an adult of its kind except in size and reproductive activity.
KILOWATT ELECTRIC (kWe)	One thousand (10^3) watts of electric power.
KILOWATT HOUR (kWh)	A unit of energy used in electrical measurement equal to energy converted or consumed at a rate of 1,000 watts during a 1-hour period.
LAND-BASED DESIGN	An OTEC design in which the plant is built on land, with the intake and discharge pipes projecting into the water.
LANTERNFISH	Any of the family Myctophidae of bony fish which bear individual light organs over the sides of the body. Commonly found in the mid-water region of the subtropical and tropical ocean.



LARVA	A young and immature form of an organism that must usually undergo one or more form and size changes before assuming characteristic features of the adult.
LEGAL REGIME	Management program based upon legal guidelines.
LETHAL	Capable of causing death.
LIGHTWEIGHT CONCRETE	A type of concrete made with a lightweight inert material. Used to make structures of low weight and high insulation.

LIQUEFACTION	The process of making or becoming liquid.
MACROZOOPLANKTON	Zooplanktonic organisms with lengths between 200 and 2,000 microns, composed mainly of copepods, chaetognaths, and fish larvae.
MACROPHYTOPLANKTON	Phytoplanktonic organisms with lengths between 200 and 2,000 microns.
MACROFOULING ORGANISMS	Sessile organisms, visible to the naked eye, which affix themselves to structures exposed to seawater (e.g. barnacles, mussels, and sea anemones).
M.A.N.™ BRUSHES	Machinefactory Augsburg-Nurenberg brushes that travel through heat-exchanger tubes for removal of micro-fouling organisms.
MARINE	Pertaining to the sea.
MEGAWATT ELECTRIC (MWe)	One million (10^6) watts of electric power.
MEGAWATT HOUR (MWH)	One thousand (10^3) kilowatt hours. See kilowatt hour.
MEGAZOOPLANKTON	Zooplanktonic organisms with lengths greater than 2,000 microns, includes euphausiids, and large copepods and chaetognaths.
MEROPLANKTON	Organisms that spend only a portion of their life cycle as plankton; usually composed of floating developmental stages (i.e., eggs and larvae) of benthic and nektonic organisms. Also known as temporary plankton.
MESOPELAGIC	Relating to the oceanic depths between 200 m and 1,000 m.
METEOROLOGICAL	Relating to the atmosphere and its phenomena, especially to weather and weather forecasting.
METRIC TON	A unit of weight equal to 1,000 kg or about 2200 pounds.
MICROCLIMATE	The essentially uniform local climate of a small site or habitat.
MICROFOULING ORGANISMS	Organisms too small to be seen with the naked eye which accumulate on the hull of a structure exposed to seawater and appear as a slime film.

MICROGRAM (μg)	A unit of mass equal to one millionth (10^{-6}) of a gram.
MICROGRAM-ATOM (μg-at)	Mass of an element numerically equal to its atomic weight (in grams) divided by 10^6.
MICROMETER	A unit of length equal to one millionth (10^{-6}) of a meter.
MICRON	See MICROMETER.
MICRONEKTON	Small weak-swimming nekton such as mesopelagic fish, small squid, gelatinous organisms, and fish larvae.
MICRO-ORGANISMS	Microscopic organisms, including bacteria, protozoans, fungi, viruses, and algae.
MICROZOOPLANKTON	Planktonic animals with lengths between 20 and 200 microns, composed mainly of protozoans and juvenile copepods.
MIGRATORY ORGANISM	Organism that peridically moves from one locality to another.
MINI-OTEC	A modified barge designed to demonstrate the technical feasibility of OTEC power and to provide design, fabrication, and operation experience.
MITIGATE	To make less severe.
MIXED LAYER	The upper level of the ocean that is well mixed by wind and wave activity. Within this layer, temperature, salinity, and nutrient concentration values are essentially homogeneous with depth.
MODULAR	Of, relating to, or based on, any of a series of standardized units for use together.
MOLE	That amount of substance containing the same number of atoms as exactly 12 g of pure carbon-12. The mass in grams of a mole of a substance is equal to the atomic or molecular weight.
MONITORING	As considered herein, the observation of environmental effects of OTEC operations through biological, physical and chemical data collection and analyses.
MOORED PLANTSHIP	An OTEC plantship moored on the water by single- or multiple-anchor systems.

MORTALITY	The death of individuals of a population.
MOTILE	Exhibiting or capable of spontaneous movement.
MULTIPLICATIVE	Tending or having the power to increase greatly in numbers.
NANNOPLANKTON	Minute planktonic plants and animals that are 50 microns or less in size and include algae, bacteria, and protozoans. Individuals of this size will pass through most nets and are usually collected in centrifuges.
NEAR FIELD	The region in which the plume momentum is the dominant factor controlling entrainment and mixing of the plume with the ambient receiving waters.
NEARSHORE ZONE	The zone extending seaward from the shore to a distance where the water column is under minimal influence from continental conditions.
NEKTON	Free-swimming aquatic animals, essentially moving independent of water movements.
NERITIC	Pertaining to the region of shallow water adjoining the seacoast and extending from the low-tide mark to a depth of about 200 m.
NET ENERGY	Energy output from generating system after deduction of energy involved in system operation.
NET POWER	Total power remaining after deduction of power required for system operation.
NEUROTOXIN	A poisonous protein complex that acts on the nervous system.
NONCONVENTIONAL POLLUTANT	A pollutant not listed by the EPA in the Clean Water Act as a toxic pollutant (Section 307 (a) (1)) or a conventional pollutant (Section 304 (b) (4)).
NONRENEWABLE FUELS	Fuels, such as fossil fuels, which are regenerated at a slower rate than they are consumed, or which cannot be regenerated.
NONTARGET PLANKTON	Plankton, usually outside the generating plant, toward which biofouling control methods are not expressly directed.

NUISANCE SPECIES	Organisms of no commercial value, which, because of predation or competition, may be harmful to commercially important organisms.
NURSERY	A protected area where the larval and juvenile stages of organisms can feed and develop.
NUTRIENT	Any substance that promotes growth or provides energy for biological processes.
OCEANIC	The portion of the pelagic zone seaward from the approximate edge of the continental shelf.
OFFSHORE ZONE	A region in which physical properties are influenced only slightly by continental conditions.
OIL TRACT	A parcel of land designated by the U.S. Department of the Interior for exploration and recovery of oil resources.
ONE-HUNDRED YEAR STORM	The most severe storm expected to occur in a one hundred year period.
ONE-PERCENT LIGHT PENERATION DEPTH	The depth at which light has been attenuated to 1% of its surface value, used to define the photic zone, that depth above which net productivity of phytoplankton can occur.
OPEN-CYCLE SYSTEM	An OTEC power system in which both coolant and working fluid are seawater and pass through the plant only once before being discharged.
OPERATING CONDITIONS	The maximum values of winds, waves, or currents below which an OTEC plant is able to operate.
OPERATIONAL SITE	Location of an operating OTEC plant.
ORGANIC COMPOUND	A compound containing carbon.
ORGANOHALOGEN	A molecule containing a carbon-halogen linkage.
ORTHO-PHOSPHATE	One of the possible salts of orthophosphoric acid; one of the components in seawater of fundamental importance to the growth of marine phytoplankton.
OTEC	Ocean Thermal Energy Conversion.
OTEC-1	A 1-MWe OTEC test platform that is presently testing power system designs, materials, and cleaning methods at Ke-ahole Point, Hawaii.

OUTGASSING	Removal of gasses from a material or space.
OXIDANT SPECIES	An atom, molecule, or ion that is capable of performing as an oxidizing agent.
OXIDATION	The combination of a substance with oxygen; a reaction in which the atoms in an element lose electrons and the valence of the element is correspondingly increased. Examples of oxidation are the rusting of iron, the burning of wood in air, and the decay of animal and plant material.
OXYGEN MININUM LAYER	A subsurface layer in the water column in which the concentration of dissolved oxygen is lower than in the layers above or below.
PARAMETERS	Any of a set of arbitrary physical properties whose values determine the characteristics or behavior of something (e.g., temperature, pressure and density); a characteristic element.
PARTIALLY EVACUATED	Having a partial vacuum.
PARTS PER THOUSAND (ppt, $^{o}/oo$)	A unit of concentration of a mixture that denotes the number of parts of a constituent contained per thousand parts of the entire mixture (e.g., g kg^{-1}, ml liter $^{-1}$). For example, the average salinity of sea water is usually reported to be 35 $^{o}/oo$, indicating 35 parts total salts per 1,000 parts seawater (including the salts).
PELAGIC	Pertaining to the open sea or organisms not associated with the bottom.
PENSTOCK	A sluice or gate for regulating a flow. A conduit or pipe for conducting water.
PHOTIC ZONE	The layer of the ocean from the surface to the depth where light has been attenuated to 1% of the surface value. The zone in which primary production shows a net increase.
PHOTOSYNTHESIS	Synthesis by chlorophyll-containing plant cells of organic compounds from carbon dioxide and a hydrogen source, with simultaneous liberation of oxygen.
PHYTOPLANKTON	Mostly microscopic passively floating plant life of a body of water; the base of the food chain in the sea.

PISCIVORES — Organisms which feed or subsist principally or entirely on fish.

PLANKTIVORES — Organisms which feed or subsist principally or entirely on plankton.

PLANKTON — Organisms whose movements are determined by the currents and not by their own locomotive abilities.

PLANT(S) — The land, building, machinery, apparatus, and fixtures employed in carrying on a trade or an industrial business (e.g. an OTEC plant).

PLANTSHIP — An OTEC plant situated on a floating self-propelled platform that also contains facilities for the manufacture of an energy-intensive product.

PLUME — See DISCHARGE PLUME.

PLUME DYNAMICS — The motion of a plume under the influence of forces which originate outside the plume. That branch of fluid mechanics which deals with the motion of a plume under the influence of outside forces.

POINT SOURCE — A source having a definite position but no extension in space; this is an ideal that is a good approximation for distances from the source that are large compared to the dimensions of the source.

POMACENTRID — Tropical fishes, 5 to 25 cm long, of the family Pomacentridae, also called damselfish.

POPULATION DYNAMICS — The sequence of population changes characteristic of particular organisms. The study of population change.

POTENTIAL IMPACT — Impact resulting from an accident, such as the accidental release of working fluid.

POWER GRID — See ELECTRICAL GRID.

POWER SYSTEM — The power-producing portion of a generating plant (e.g., turbine and working fluid system).

PREDATOR — An animal that procures food primarily through the killing and consuming of other animals.

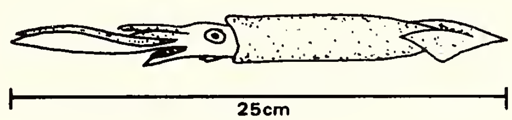
PRIMARY PRODUCTION — The amount of organic matter synthesized by organisms from inorganic substances per unit time and unit volume of water, or in a column of water of unit area extending from the surface to the bottom.

PROTOZOA	Mostly microscopic, single-celled animals which constitute one of the largest populations in the ocean. Protozoans play a major role in the recycling of nutrients.
REACTIVITY	The tendency of a substance to combine (react) with another substance.
RECRUITMENT	Increase in a population through the addition of new individuals.
RECRUITMENT STOCK	That portion of a population from which recruitment can occur.
RED TIDE	A red or reddish-brown discoloration of surface waters most frequently found in coastal regions, caused by high concentrations of dinoflagellates.
REFERENCE OR AFFECTED WATER COLUMN	The volume of water that may be potentially affected by OTEC operation.
RENEWABLE ENERGY	Energy derived from a source that is quickly regenerated.
RESIDUAL CHLORINE	See TOTAL RESIDUAL CHLORINE.
RESPIRATION	The interchange of gases between an organism and its environment. The liberation of energy within, and its utilization by, a cell, also called internal respiration.
RESPIRATORY SURFACE	The tissue of an organism that is used for the interchange of gases between the organism and its environment.
SALINITY	The amount of dissolved salts in seawater measured in grams per kilogram, or parts per thousand.
SALT	Any substance that yields ions other than hydrogen or hydroxyl ions. Obtained by displacing the hydrogen of an acid by a metal.
SARGASSUM SHRIMP	A shrimp of the species *Latreutus fucorum*.
SAURY	A billfish of the species *Scomberesox saurus* (family Belonidae). It is distributed worldwide in temperate and warm seas.

SCOMBROID	Any of the suborder Scombroidea of marine spiny fishes, such as mackarels, tunas, and albacores, of great economic importance as food fishes.
SCRUBBER	A device for the removal or washing out of entrained fluid droplets, dust, or undesired gas components.
SEA BED	See SEA FLOOR.
SEA FLOOR	The bottom of the ocean.
SEA STATE	The numerical or written description of wind-generated waves on the surface of the sea, ranging from 1 (smooth) to 8 (mountainous).
SERIOLA SPP.	A large vigorous sport fish of the family Carangidae. Commonly called amberjack. See CARANGID.
SHEAR FORCES	Applied forces that cause or tend to cause two adjacent parts of a substance to move relative to each other in a direction parallel to their plane of contact.
SHELLFISH	Any invertebrate, usually of commercial importance, having a rigid outer covering, such as a shell or exoskeleton, includes some molluscs and arthropods. Term is the counterpart of finfish.
SHORELINE	The boundary between a body of water and the land at high tide.
SIGNAL	A detectable physical quantity or impulse by which messages or information can be transmitted.
SLIDE	The descent of a mass of earth or rock down a slope.
SLOPE	The angle at which an inclined surface deviates from the horizontal. Any portion of the earth's surface that deviates from the horizontal.
SOFAR	An acronym derived from the expression "sound fixing and ranging". See DEEP SOUND CHANNEL.
SPAR	A long, thin, typically cylindrical structure ballasted at one end so that it floats in an approximately vertical position.
SPAR BUOY RISER	An independently moored, retrievable pipe that is buoyant, allowing connection to the mother ship.

SPAWNING GROUND	An area used by aquatic animals for the release of sperm and eggs.
SPECIES	A group of organisms having similar characteristics and capable of interbreeding and producing viable offspring. A taxon forming basic taxonomic groups that closely resemble each other structurally and physiologically and, in nature, interbreed and produce fertile offspring.
SPONSON	Any structure projecting from the side of a ship or hull.
STABILIZATION DEPTH	The depth at which a mass of water will neither rise nor sink.
STANDING STOCK	The biomass or abundance of living material per unit volume or area.
STATIC SCREENS	Intake screens that are fixed in position.
STRESSED	A state caused by factors that tend to alter an existent equilibrium or normal state.
STRUMMING	The establishment of transverse vibrations in a cable with fixed endpoints, usually caused by current or wind.
SUBLETHAL	Less than lethal, injurious but not fatal.
SUBSTRATE	The solid material upon which an organism lives, or to which it is attached (e.g., rocks, sand).
SUMP	A pit or reservoir serving as a drain or receptacle for liquids.
SURFACTANT	A soluble compound that reduces the surface tension of a liquid or reduces interfacial tension between two liquids or a liquid and a solid. It often works through the production of a liquid foam.
SURVEILLANCE	Systematic observation of an area by visual, electronic, photographic, or other means for the purpose of ensuring compliance with applicable laws, regulations, permits, and safety regulations.
SURVIVAL CONDITIONS	The maximum intensities of winds, waves, and currents that a structure can endure without sustaining permanent damage.

SUSPENDED SOLIDS	Finely divided particles of a solid temporarily suspended in a liquid (e.g., sediment particles in water), expressed as a weight per unit volume.
SYNERGISTIC EFFECTS	Effects capable of acting in synergism.
SYNERGISM	The interaction between two or more effects to produce an effect greater than the sum of the individual effects.
SQUID	Any of numerous 10-armed cephalopods having a long tapered body, a caudal fin on each side, and usually a slender internal chitonous support (especially genus *Loligo* and *Ommastrephes*).



TAXA	Two or more of a hierarchy of levels in the biological classification of organisms.
TEMPORAL DISTRIBUTION	The distribution of a parameter over a period of time.
TERRIGENOUS	Produced of or from land.
TERRITORIAL SEA	The area of the ocean bordering a nation over which it has exclusive jurisdiction except for the right of innocent passage of foreign vessels. Its seaward limit is less than or equal to 12 nmi. The United States has traditionally claimed 3 nmi, with the exception of Puerto Rico, which claims 10.8 nmi, and Florida and Texas, which claim 9 nmi in the Gulf of Mexico.
THERMAL CONDUCTIVITY	The heat flow across a surface per unit area per unit time, divided by the negative of the rate of change of temperature with distance in a direction perpendicular to the surface.
THERMAL EFFICIENCY	The ratio of the work done by a heat engine to the heat energy absorbed by it.
THERMAL GRADIENT	The change in temperature with a change in distance, usually depth.

THERMAL RESOURCE	The source of temperature differential required for OTEC operation. A temperature differential of 20°C between surface waters and 1,000 m is usually considered an adequate thermal resource. A good thermal resource has a strong temperature gradient and a well established thermocline, and consequently is not easily depleted.
THERMAL SHOCK	A state of profound depression of an organism's vital processes induced by an abrupt change in ambient temperature.
THERMOCLINE	The region of the water column where temperature changes most rapidly with depth.
THERMOPLASTIC PAINT	Paint that is capable of softening or fusing when heated and of hardening again when cooled.
THREATENED SPECIES	Any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. (Endangered Species Act of 1973, P.L. 93-205).
TISSUE	An aggregate of cells, usually of a particular kind, together with their intercellular substance, that form one of the structural materials of a plant or animal.
TOTAL RESIDUAL CHLORINE (TRC)	The summation of the concentrations of various chlorine compounds in water, including hypochlorous acid, hypochlorite ion, chloramines, and other chlorine derivatives.
TOXICITY	The degree to which a substance is poisonous to an organism.
TOXICITY STUDY	The addition of a specific pollutant to a sample of natural waters containing a number of test organisms to determine the toxicity of the pollutant to the organisms.
TOXIC POLLUTANT	A pollutant listed by the EPA in the Clean Water Act as a toxic pollutant (section 307(a)(11)).
TRACE CONSITITUENT	An element or compound found in the environment in extremely small quantities.
TRACE METAL OR ELEMENT	An element found in the environment in extremely small quantities; usually includes metals constituting 0.1% (1,000 ppm) or less, by weight, in the earth's crust.

TRADE WINDS — The wind system that occupies most of the tropics, generally blowing from the subtropical highs towards the equatorial trough. The winds are northeasterly in the Northern Hemisphere and southeasterly in the Southern Hemisphere.

TRAVELING SCREEN — Mesh screen attached to an OTEC plant intake to prevent the intake of materials that could clog the heat exchangers.

TROPHIC LEVELS — Discrete steps along a food chain in which energy is transferred from the primary producers (plants) to herbivores and finally to carnivores and decomposers.

TROPICAL CYCLONE — A type of atmospheric disturbance, originating between 25° north and south latitudes, characterized by masses of air rapidly circulating (clockwise in the Southern Hemisphere and counterclockwise in the Northern Hemisphere) around a low-pressure center. Tropical cyclones are usually accompanied by stormy, often destructive, weather.

TSUNAMI — A long period sea wave produced by a submarine earthquake or volcanic eruption.

TUNA — Any of numerous large vigorous scombroid food and sport fishes. See SCOMBROID.

TURBIDITY — A reduction in transparency, as in seawater, caused by suspended particulate such as sediments or plankton.

TURBINE — A rotary engine actuated by the reaction or impulse, or both, of a current of fluid or vapor subject to pressure.

TURBULENT DIFFUSION — The transfer of matter by turbulent eddies in a fluid.

TURBULENT EDDY — An eddy in which the instantaneous velocities exhibit irregular and apparently random fluctuations.

TURNOVER RATE — The time necessary to completely replace the standing stock of a population; generation time.

UPWELLING — The rising of water toward the surface from subsurface layers of a body of water. Upwelling is most prominent where persistent winds blow parallel to a coastline so that the resultant water current sets away from the coast. The upwelled water, besides being cooler, is rich in nutrients, so that upwelling regions generally have rich fisheries.

ULTRASONIC	Having a frequency higher than the human ear's audibility limit of about 20,000 cycles per second.
UTILITY CORRIDOR	A strip of land designated for the transfer of a public utility.
UTILITY TERMINUS	Either end of a utility distribution system.
VACUUM	A space in which the pressure is so far below normal atmospheric pressure that the remaining gases do not affect processes being carried on.
VAPORIZE	The conversion of a substance from liquid or solid state to a vapor state by the application of heat, reduction of pressure, or both.
VAPOR PRESSURE	The pressure exerted by the molecules of a given vapor.
VELOCITY CAP	Restriction plate placed over intake ports to change direction and velocity of inflow.
VERTICAL DISTRIBUTION	The frequency of occurrence over an area in the vertical plane.
WARM-WATER PIPE	That component of the OTEC plant through which the warm surface water used to vaporize the working fluid is drawn.
WATCH CIRCLE RADIUS	The horizontal distance between a free-floating vessel and the buoy or anchor to which it is tethered.
WATER COLUMN	A vertical section of the ocean used in relation to descriptions of oceanographic parameters.
WATER MASS	A body of water usually identified by its temperature-salinity (T-S) curve or its chemical content.
WATT	A unit of power equal to the rate of work represented by one ampere under a pressure of one volt; taken as the standard in the U.S.
WORKING FLUID	The medium in an OTEC plant that is vaporized by warm ocean water, passed over a turbine to generate electricity, and finally condensed by cool ocean water.
ZOOPLANKTON	The passively floating or weakly swimming animals of an aquatic ecosystem.

Abbreviations

APC	Area of Particular Concern
atm	atmosphere
BTU	British Thermal Unit
C	carbon
CO_2	carbon dioxide
cm	centimeter(s)
cm sec^{-1}	centimeters per second
CW	cold water
^oC	degrees Celsius or centigrade
dB	decibel
DOC	United States Department of Commerce
DOE	United States Department of Energy
EA	environmental assessment
EEZ	Exclusive Economic Zone
EIS	Environmental Impact Statement
EPA	United States Environmental Protection Agency
FWPCA	Federal Water Pollution Control Act
GCRL	Gulf Coast Research Laboratories
g C m^{-2} yr^{-1}	grams carbon per square meter per year
GWe	gigawatt electric
HEW	U.S. Department of Health, Education and Welfare
Hz	hertz
IEC	Interstate Electronics Corporation
kg	kilogram(s)
kg C	kilogram(s) carbon
kg C day^{-1}	kilogram(s) carbon per day
km	kilometer(s)
km^2	square kilometer(s)
kWe	kilowatt electric
kWh	kilowatt hour(s)

m	meter(s)
m^2	square meter(s)
m^3	cubic meter(s)
$m\ sec^{-1}$	meters per second
$m^3\ day^{-1}$	cubic meters per day
$m^3\ MWe^{-1}$	cubic meters per megawatt electric
$m^3\ sec^{-1}$	cubic meters per second
MWe	megawatt electric
MWh	megawatt hour
NH_3	ammonia
NEPA	National Environmental Policy Act of 1969
nmi	nautical miles
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
OME	Office of Ocean Minerals and Energy
OTEC	Ocean Thermal Energy Conversion
ppm	parts per million
ppt	parts per thousand
SMA	Special Management Area
sec	second(s)
S/N	signal-to-noise ratio
SST	sea-surface temperature
tons C yr^{-1}	tons of carbon per year
μ	micron
μg	microgram

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Appendix A

OTEC LEGISLATION

OCEAN THERMAL ENERGY CONVERSION ACT OF 1980
(PL 96-320 – AUGUST 3, 1980)

Public Law 96-320
96th Congress

An Act

Aug. 3, 1980
[S. 2492]

To regulate commerce, promote energy self-sufficiency, and protect the environment, by establishing procedures for the location, construction, and operation of ocean thermal energy conversion facilities and plantships to produce electricity and energy-intensive products off the coasts of the United States; to amend the Merchant Marine Act, 1936, to make available certain financial assistance for construction and operation of such facilities and plantships; and for other purposes.

Ocean Thermal Energy Conversion Act of 1980.
42 USC 9101 note.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "Ocean Thermal Energy Conversion Act of 1980".

42 USC 9101.

SEC. 2. DECLARATION OF POLICY.

(a) It is declared to be the purposes of the Congress in this Act to—

(1) authorize and regulate the construction, location, ownership, and operation of ocean thermal energy conversion facilities connected to the United States by pipeline or cable, or located in the territorial sea of the United States consistent with the Convention on the High Seas, and general principles of international law;

(2) authorize and regulate the construction, location, ownership, and operation of ocean thermal energy conversion plantships documented under the laws of the United States, consistent with the Convention on the High Seas and general principles of international law;

(3) authorize and regulate the construction, location, ownership, and operation of ocean thermal energy conversion plantships by United States citizens, consistent with the Convention on the High Seas and general principles of international law;

(4) establish a legal regime which will permit and encourage the development of ocean thermal energy conversion as a commercial energy technology;

(5) provide for the protection of the marine and coastal environment, and consideration of the interests of ocean users, to prevent or minimize any adverse impact which might occur as a consequence of the development of such ocean thermal energy conversion facilities or plantships;

(6) make applicable certain provisions of the Merchant Marine Act, 1936 (46 U.S.C. 1177 et seq.) to assist in financing of ocean thermal energy conversion facilities and plantships;

(7) protect the interests of the United States in the location, construction, and operation of ocean thermal energy conversion facilities and plantships; and

(8) protect the rights and responsibilities of adjacent coastal States in ensuring that Federal actions are consistent with approved State coastal zone management programs and other applicable State and local laws.

(b) The Congress declares that nothing in this Act shall be construed to affect the legal status of the high seas, the superjacent airspace, or the seabed and subsoil, including the Continental Shelf.

SEC. 3. DEFINITIONS. 42 USC 9102.

As used in this Act, unless the context otherwise requires, the term—

(1) "adjacent coastal State" means any coastal State which is required to be designated as such by section 105(a)(1) of this Act or is designated as such by the Administrator in accordance with section 105(a)(2) of this Act;

(2) "Administrator" means the Administrator of the National Oceanic and Atmospheric Administration;

(3) "antitrust laws" includes the Act of July 2, 1890, as amended, the Act of October 15, 1914, as amended, and sections 73 and 74 of the Act of August 27, 1894, as amended; 15 USC 1, 12, 8, 9.

(4) "application" means any application submitted under this Act (A) for issuance of a license for the ownership, construction, and operation of an ocean thermal energy conversion facility or plantship; (B) for transfer or renewal of any such license; or (C) for any substantial change in any of the conditions and provisions of any such license;

(5) "coastal State" means a State in, or bordering on, the Atlantic, Pacific, or Arctic Ocean, the Gulf of Mexico, Long Island Sound, or one or more of the Great Lakes;

(6) "construction" means any activities conducted at sea to supervise, inspect, actually build, or perform other functions incidental to the building, repairing, or expanding of an ocean thermal energy conversion facility or plantship or any of its components, including but not limited to, piledriving, emplacement of mooring devices, emplacement of cables and pipelines, and deployment of the cold water pipe, and alterations, modifications, or additions to an ocean thermal energy conversion facility or plantship;

(7) "facility" means an ocean thermal energy conversion facility;

(8) "Governor" means the Governor of a State or the person designated by law to exercise the powers granted to the Governor pursuant to this Act;

(9) "high seas" means that part of the oceans lying seaward of the territorial sea of the United States and outside the territorial sea, as recognized by the United States, of any other nation;

(10) "licensee" means the holder of a valid license for the ownership, construction, and operation of an ocean thermal energy conversion facility or plantship that was issued, transferred, or renewed pursuant to this Act;

(11) "ocean thermal energy conversion facility" means any facility which is standing or moored in or beyond the territorial sea of the United States and which is designed to use temperature differences in ocean water to produce electricity or another form of energy capable of being used directly to perform work, and includes any equipment installed on such facility to use such electricity or other form of energy to produce, process, refine, or manufacture a product, and any cable or pipeline used to deliver such electricity, freshwater, or product to shore, and all other associated equipment and appurtenances of such facility, to the extent they are located seaward of the highwater mark;

(12) "ocean thermal energy conversion plantship" means any vessel which is designed to use temperature differences in ocean water while floating unmoored or moving through such water, to produce electricity or another form of energy capable of being used directly to perform work, and includes any equipment

installed on such vessel to use such electricity or other form of energy to produce, process, refine, or manufacture a product, and any equipment used to transfer such product to other vessels for transportation to users, and all other associated equipment and appurtenances of such vessel;

(13) "plantship" means an ocean thermal energy conversion plantship;

(14) "person" means any individual (whether or not a citizen of the United States), any corporation, partnership, association, or other entity organized or existing under the laws of any nation, and any Federal, State, local or foreign government or any entity of any such government;

(15) "State" means each of the several States, the District of Columbia, the Commonwealth of Puerto Rico, American Samoa, the United States Virgin Islands, Guam, the Commonwealth of the Northern Marianas, and any other Commonwealth, territory, or possession over which the United States has jurisdiction;

(16) "test platform" means any floating or moored platform, barge, ship, or other vessel which is designed for limited-scale, at sea operation in order to test or evaluate the operation of components or all of an ocean thermal energy conversion system and which will not operate as an ocean thermal energy conversion facility or plantship after the conclusion of such tests or evaluation;

(17) "thermal plume" means the area of the ocean in which a significant difference in temperature, as defined in regulations by the Administrator, occurs as a result of the operation of an ocean thermal energy conversion facility or plantship; and

(18) "United States citizen" means (A) any individual who is a citizen of the United States by law, birth, or naturalization; (B) any Federal, State, or local government in the United States, or any entity of any such government; or (C) any corporation, partnership, association, or other entity, organized or existing under the laws of the United States, or of any State, which has as its president or other executive officer and as its chairman of the board of directors, or holder of similar office, an individual who is a United States citizen and which has no more of its directors who are not United States citizens than constitute a minority of the number required for a quorum necessary to conduct the business of the board.

TITLE I—REGULATION OF OCEAN THERMAL ENERGY CONVERSION FACILITIES AND PLANTSHIPS

42 USC 9111.

SEC. 101. LICENSE FOR THE OWNERSHIP, CONSTRUCTION, AND OPERATION OF AN OCEAN THERMAL ENERGY CONVERSION FACILITY OR PLANTSHIP.

(a) No person may engage in the ownership, construction, or operation of an ocean thermal energy conversion facility which is documented under the laws of the United States, which is located in the territorial sea of the United States, or which is connected to the United States by pipeline or cable, except in accordance with a license issued pursuant to this Act. No citizen of the United States may engage in the ownership, construction or operation of an ocean thermal energy conversion plantship except in accordance with a license issued pursuant to this Act, or in accordance with a license issued by a foreign nation whose licenses are found by the Administrator, after consultation with the Secretary of State, to be compatible with licenses issued pursuant to this Act.

(b) The Administrator shall, upon application and in accordance with the provisions of this Act, issue, transfer, amend, or renew licenses for the ownership, construction, and operation of—

(1) ocean thermal energy conversion plantships documented under the laws of the United States, and

(2) ocean thermal energy conversion facilities documented under the laws of the United States, located in the territorial sea of the United States, or connected to the United States by pipeline or cable.

License issuance, prerequisites.

(c) The Administrator may issue a license to a citizen of the United States in accordance with the provisions of this Act unless—

(1) he determines that the applicant cannot and will not comply with applicable laws, regulations, and license conditions;

(2) he determines that the construction and operation of the ocean thermal energy conversion facility or plantship will not be in the national interest and consistent with national security and other national policy goals and objectives, including energy self-sufficiency and environmental quality;

(3) he determines, after consultation with the Secretary of the department in which the Coast Guard is operating, that the ocean thermal energy conversion facility or plantship will not be operated with reasonable regard to the freedom of navigation or other reasonable uses of the high seas and authorized uses of the Continental Shelf, as defined by United States law, treaty, convention, or customary international law;

(4) he has been informed, within 45 days after the conclusion of public hearings on that application, or on proposed licenses for the designated application area, by the Administrator of the Environmental Protection Agency that the ocean thermal energy conversion facility or plantship will not conform with all applicable provisions of any law for which he has enforcement authority;

(5) he has received the opinion of the Attorney General, pursuant to section 104 of this Act, stating that issuance of the license would create a situation in violation of the antitrust laws, or the 90-day period provided in section 104 has expired;

(6) he has consulted with the Secretary of Energy, the Secretary of Transportation, the Secretary of State, the Secretary of the Interior, and the Secretary of Defense, to determine their views on the adequacy of the application, and its effect on programs within their respective jurisdictions and determines on the basis thereof, that the application for license is inadequate;

(7) the proposed ocean thermal energy conversion facility or plantship will not be documented under the laws of the United States;

(8) the applicant has not agreed to the condition that no vessel may be used for the transportation to the United States of things produced, processed, refined, or manufactured at the ocean thermal energy conversion facility or plantship unless such vessel is documented under the laws of the United States;

(9) when the license is for an ocean thermal energy conversion facility, he determines that the facility, including any submarine electric transmission cables and equipment or pipelines which are components of the facility, will not be located and designed so as to minimize interference with other uses of the high seas or

the Continental Shelf, including cables or pipelines already in position on or in the seabed and the possibility of their repair;

16 USC 1451 et seq.

(10) the Governor of each adjacent coastal State with an approved coastal zone management program in good standing pursuant to the Coastal Zone Management Act of 1972 (33 U.S.C. 1451 et seq.) determines that, in his or her view, the application is inadequate or inconsistent with respect to programs within his or her jurisdiction;

(11) when the license is for an ocean thermal energy conversion facility, he determines that the thermal plume of the facility is expected to impinge on so as to degrade the thermal gradient used by any other ocean thermal energy conversion facility already licensed or operating, without the consent of its owner;

(12) when the license is for an ocean thermal energy conversion facility, he determines that the thermal plume of the facility is expected to impinge on so as to adversely affect the territorial sea or area of national resource jurisdiction, as recognized by the United States, of any other nation, unless the Secretary of State approves such impingement after consultation with such nation;

(13) when the license is for an ocean thermal energy conversion plantship, he determines that the applicant has not provided adequate assurance that the plantship will be operated in such a way as to prevent its thermal plume from impinging on so as to degrade the thermal gradient used by any other ocean thermal energy conversion facility or plantship without the consent of its owner, and from impinging on so as to adversely affect the territorial sea or area of national resource jurisdiction, as recognized by the United States, of any other nation unless the Secretary of State approves such impingement after consultation with such nation; and

(14) when a regulation has been adopted which places an upper limit on the number or total capacity of ocean thermal energy conversion facilities or plantships to be licensed under this Act for simultaneous operation, either overall or within specific geographic areas, pursuant to a determination under the provisions of section 107(b)(4) of this Act, issuance of the license will cause such upper limit to be exceeded.

Issuance conditions.

(d)(1) In issuing a license for the ownership, construction, and operation of an ocean thermal energy conversion facility or plantship, the Administrator shall prescribe conditions which he deems necessary to carry out the provisions of this Act, or which are otherwise required by any Federal department or agency pursuant to the terms of this Act.

Written agreement of compliance.

(2) No license shall be issued, transferred, or renewed under this Act unless the licensee or transferee first agrees in writing that (A) there will be no substantial change from the plans, operational systems, and methods, procedures, and safeguards set forth in his application, as approved, without prior approval in writing from the Administrator, and (B) he will comply with conditions the Administrator may prescribe in accordance with the provisions of this Act.

Disposal or removal requirements.

(3) The Administrator shall establish such bonding requirements or other assurances as he deems necessary to assure that, upon the revocation, termination, relinquishment, or surrender of a license, the licensee will dispose of or remove all components of the ocean thermal energy conversion facility or plantship as directed by the Administrator.

Waiver.

In the case of components which another applicant or licensee desires to use, the Administrator may waive the disposal or removal requirements until he has reached a decision on the application. In the case of components lying on or below the seabed, the Administrator may waive the disposal or removal requirements if he finds that such removal is not otherwise necessary and that the remaining components do not constitute any threat to the environment, navigation, fishing, or other uses of the seabed.

License transfer.

(e) Upon application, a license issued under this Act may be transferred if the Administrator determines that such transfer is in the public interest and that the transferee meets the requirements of this Act and the prerequisites to issuance under subsection (c) of this section.

(f) Any United States citizen who otherwise qualifies under the terms of this Act shall be eligible to be issued a license for the ownership, construction, and operation of an ocean thermal energy conversion facility or plantship.

License term and renewal.

(g) Licenses issued under this Act shall be for a term of not to exceed 25 years. Each licensee shall have a preferential right to renew his license subject to the requirements of subsection (c) of this section, upon such conditions and for such term, not to exceed an additional 10 years upon each renewal, as the Administrator determines to be reasonable and appropriate.

SEC. 102. PROCEDURE.

42 USC. 9112.

Regulations.

(a) The Administrator shall, after consultation with the Secretary of Energy and the heads of other Federal agencies, issue regulations to carry out the purposes and provisions of this Act, in accordance with the provisions of section 553 of title 5, United States Code, without regard to subsection (a) thereof. Such regulations shall pertain to, but need not be limited to, application for issuance, transfer, renewal, suspension, and termination of licenses. Such regulations shall provide for full consultation and cooperation with all other interested Federal agencies and departments and with any potentially affected coastal State, and for consideration of the views of any interested members of the general public. The Administrator is further authorized, consistent with the purposes and provisions of this Act, to amend or rescind any such regulation. The Administrator shall complete issuance of final regulations to implement this Act within 1 year of the date of its enactment.

Consultation.

(b) The Administrator, in consultation with the Secretary of the Interior and the Secretary of the department in which the Coast Guard is operating may, if he determines it to be necessary, prescribe regulations consistent with the purposes of this Act, relating to those activities in site evaluation and preconstruction testing at potential ocean thermal energy conversion facility or plantship locations that may (1) adversely affect the environment; (2) interfere with other reasonable uses of the high seas or with authorized uses of the Outer Continental Shelf; or (3) pose a threat to human health and safety. If the Administrator prescribes regulations relating to such activities, such activities may not be undertaken after the effective date of such regulations except in accordance therewith.

Expertise or statutory responsibility descriptions.

(c) Not later than 60 days after the date of enactment of this Act, the Secretary of Energy, the Administrator of the Environmental Protection Agency, the Secretary of the department in which the Coast Guard is operating, the Secretary of the Interior, the Chief of Engineers of the United States Army Corps of Engineers, and the heads of any other Federal departments or agencies having expertise concerning, or jurisdiction over, any aspect of the construction or operation of ocean thermal energy conversion facilities or plantships, shall transmit to the Administrator written description of their

expertise or statutory responsibilities pursuant to this Act or any other Federal law.

Application receipt and notice.

Publication in Federal Register.

(d)(1) Within 21 days after the receipt of an application, the Administrator shall determine whether the application appears to contain all of the information required by paragraph (2) of this subsection. If the Administrator determines that such information appears to be contained in the application, the Administrator shall, no later than 5 days after making such a determination, publish notice of the application and a summary of the plans in the Federal Register. If the Administrator determines that all of the required information does not appear to be contained in the application, the Administrator shall notify the applicant and take no further action with respect to the application until such deficiencies have been remedied.

(2) Each application shall include such financial, technical, and other information as the Administrator determines by regulation to be necessary or appropriate to process the license pursuant to section 101.

Area description, publication in Federal Register.

(e)(1) At the time notice of an application for an ocean thermal energy conversion facility is published pursuant to subsection (d) of this section, the Administrator shall publish a description in the Federal Register of an application area encompassing the site proposed in the application for such facility and within which the thermal plume of one ocean thermal energy conversion facility might be expected to impinge on so as to degrade the thermal gradient used by another ocean thermal energy conversion facility, unless the application is for a license for an ocean thermal energy conversion facility to be located within an application area which has already been designated.

Additional license applications.

(2) The Administrator shall accompany such publication with a call for submission of any other applications for licenses for the ownership, construction, and operation of an ocean thermal energy conversion facility within the designated application area. Any person intending to file such an application shall submit a notice of intent to file an application to the Administrator not later than 60 days after the publication of notice pursuant to subsection (d) of this section, and shall submit the completed application no later than 90 days after publication of such notice. The Administrator shall publish notice of any such application received in accordance with subsection (d) of this section. No application for a license for the ownership, construction, and operation of an ocean thermal energy conversion facility within the designated application area for which a notice of intent to file was received after such 60-day period, or which is received after such 90-day period has elapsed, shall be considered until action has been completed on all timely filed applications pending with respect to such application area.

Application copies.

(f) An application filed with the Administrator shall constitute an application for all Federal authorizations required for ownership, construction, and operation of an ocean thermal energy conversion facility or plantship, except for authorizations required by documentation, inspection, certification, construction, and manning laws and regulations administered by the Secretary of the department in which the Coast Guard is operating. At the time notice of any application is published pursuant to subsection (d) of this section, the Administrator shall forward a copy of such application to those Federal agencies and departments with jurisdiction over any aspect of such ownership, construction, or operation for comment, review, or recommendation as to conditions and for such other action as may be

Application review.

required by law. Each agency or department involved shall review the application and, based upon legal considerations within its area of responsibility, recommend to the Administrator the approval or disapproval of the application not later than 45 days after public hearings are concluded pursuant to subsection (g) of this section. In any case in which an agency or department recommends disapproval, it shall set forth in detail the manner in which the application does not comply with any law or regulation within its area of responsibility and shall notify the Administrator of the manner in which the application may be amended or the license conditioned so as to bring it into compliance with the law or regulation involved.

Notice, comments, and hearings.

(g) A license may be issued, transferred, or renewed only after public notice, opportunity for comment, and public hearings in accordance with this subsection. At least one such public hearing shall be held in the District of Columbia and in any adjacent coastal State to which a facility is proposed to be directly connected by pipeline or electric transmission cable. Any interested person may present relevant material at any such hearing. After the hearings required by this subsection are concluded, if the Administrator determines that there exist one or more specific and material factual issues which may be resolved by a formal evidentiary hearing, at least one adjudicatory hearing shall be held in the District of Columbia in accordance with the provisions of section 554 of title 5, United States Code. The record developed in any such adjudicatory hearing shall be part of the basis for the Administrator's decision to approve or deny a license. Hearings held pursuant to this subsection shall be consolidated insofar as practicable with hearings held by other agencies. All public hearings on all applications with respect to facilities for any designated application area shall be consolidated and shall be concluded not later than 240 days after notice of the initial application has been published pursuant to subsection (d) of this section. All public hearings on applications with respect to ocean thermal energy conversion plantships shall be concluded not later than 240 days after notice of the application has been published pursuant to subsection (d) of this section.

Record.

Consolidation of hearings.

Application fee.

(h) Each person applying for a license pursuant to this Act shall remit to the Administrator at the time the application is filed a nonrefundable application fee, which shall be deposited into miscellaneous receipts of the Treasury. The amount of the fee shall be established by regulation by the Administrator, and shall reflect the reasonable administrative costs incurred in reviewing and processing the application.

Application approval or denial.

(i)(1) The Administrator shall approve or deny any timely filed application with respect to a facility for a designated application area submitted in accordance with the provision of this Act not later than 90 days after public hearings on proposed licenses for that area are concluded pursuant to subsection (g) of this section. The Administrator shall approve or deny an application for a license for ownership, construction, and operation of an ocean thermal energy conversion plantship submitted pursuant to this Act no later than 90 days after the public hearings on that application are concluded pursuant to subsection (g) of this section.

Applications for same area.

(2) In the event more than one application for a license for ownership, construction, and operation of an ocean thermal energy conversion facility is submitted pursuant to this Act for the same designated application area, the Administrator, unless one or a specific combination of the proposed facilities clearly best serves the

national interest, shall make decisions on license applications in the order in which they were submitted to him.

Facility selection, determination factors.

(3) In determining whether any one or a specific combination of the proposed ocean thermal energy conversion facilities clearly best serves the national interest, the Administrator, in consultation with the Secretary of Energy, shall consider the following factors:

(A) the goal of making the greatest possible use of ocean thermal energy conversion by installing the largest capacity practicable in each application area;

(B) the amount of net energy impact of each of the proposed ocean thermal energy conversion facilities;

(C) the degree to which the proposed ocean thermal energy conversion facilities will affect the environment;

(D) any significant differences between anticipated dates and commencement of operation of the proposed ocean thermal energy conversion facilities; and

(E) any differences in costs of construction and operation of the proposed ocean thermal energy conversion facilities, to the extent that such differentials may significantly affect the ultimate cost of energy or products to the consumer.

42 USC 9113.

SEC. 103. PROTECTION OF SUBMARINE ELECTRIC TRANSMISSION CABLES AND EQUIPMENT.

Penalties and fines.

(a) Any person who shall willfully and wrongfully break or injure, or attempt to break or injure, or who shall in any manner procure, counsel, aid, abet, or be accessory to such breaking or injury, or attempt to break or injure, any submarine electric transmission cable or equipment being constructed or operated under a license issued pursuant to this Act shall be guilty of a misdemeanor and, on conviction thereof, shall be liable to imprisonment for a term not exceeding 2 years, or to a fine not exceeding $5,000, or to both fine and imprisonment, at the discretion of the court.

(b) Any person who by culpable negligence shall break or injure any submarine electric transmission cable or equipment being constructed or operated under a license issued pursuant to this Act shall be guilty of a misdemeanor and, on conviction thereof, shall be liable to imprisonment for a term not exceeding 3 months, or to a fine not exceeding $500, or to both fine and imprisonment, at the discretion of the court.

(c) The provisions of subsections (a) and (b) of this section shall not apply to any person who, after having taken all necessary precautions to avoid such breaking or injury, breaks or injures any submarine electric transmission cable or equipment in an effort to save the life or limb of himself or of any other person, or to save his own or any other vessel.

Suit for damages.

(d) The penalties provided in subsections (a) and (b) of this section for the breaking or injury of any submarine electric transmission cable or equipment shall not be a bar to a suit for damages on account of such breaking or injury.

Indemnity.

(e) Whenever any vessel sacrifices any anchor, fishing net, or other fishing gear to avoid injuring any submarine electric transmission cable or equipment being constructed or operated under a license issued pursuant to this Act, the licensee shall indemnify the owner of such vessel for the items sacrificed: *Provided*, That the owner of the vessel had taken all reasonable precautionary measures beforehand.

Repair cost.

(f) Any licensee who causes any break in or injury to any submarine cable or pipeline of any type shall bear the cost of the repairs.

SEC. 104. ANTITRUST REVIEW.

42 USC 9114.

Application copy, transmittal to Attorney General.

(a) Whenever any application for issuance, transfer, or renewal of any license is received, the Administrator shall transmit promptly to the Attorney General a complete copy of such application. Within 90 days of the receipt of the application, the Attorney General shall conduct such antitrust review of the application as he deems appropriate, and submit to the Administrator any advice or recommendations he deems advisable to avoid any action upon such application by the Administrator which would create a situation inconsistent with the antitrust laws. If the Attorney General fails to file such views within the 90-day period, the Administrator shall proceed as if such views had been received. The Administrator shall not issue, transfer, or renew the license during the 90-day period, except upon written confirmation by the Attorney General that he does not intend to submit any further advice or recommendation on the application during such period.

(b) The issuance of a license under this Act shall not be admissible in any way as a defense to any civil or criminal action for violation of the antitrust laws of the United States, nor shall it in any way modify or abridge any private right of action under such laws. Nothing in this section shall be construed to bar the Attorney General or the Federal Trade Commission from challenging any anticompetitive situation involved in the ownership, construction, or operation of an ocean thermal energy conversion facility or plantship.

SEC. 105. ADJACENT COASTAL STATES.

42 USC 9115.

(a)(1) The Administrator, in issuing notice of application pursuant to section 102(d) of this title, shall designate as an "adjacent coastal State" any coastal State which (A) would be directly connected by electric transmission cable or pipeline to an ocean thermal energy conversion facility as proposed in an application, or (B) in whose waters any part of such proposed ocean thermal energy conversion facility would be located, or (C) in whose waters an ocean thermal energy conversion plantship would be operated as proposed in an application.

(2) The Administrator shall, upon request of a State, designate such State as an "adjacent coastal State" if he determines that (A) there is a risk of damage to the coastal environment of such State equal to or greater than the risk posed to a State required to be designated as an "adjacent coastal State" by paragraph (1) of this subsection or (B) that the thermal plume of the proposed ocean thermal energy conversion facility or plantship is likely to impinge on so as to degrade the thermal gradient at possible locations for ocean thermal energy conversion facilities which could reasonably be expected to be directly connected by electric transmission cable or pipeline to such State. This paragraph shall apply only with respect to requests made by a State not later than the 14th day after the date of publication of notice of application for a proposed ocean thermal energy conversion facility in the Federal Register in accordance with section 102(d) of this title. The Administrator shall make any designation required by this paragraph not later than the 45th day after the date he receives such a request from a State.

Publication in Federal Register.

Application copy, transmittal to State Governor.

(b)(1) Not later than 5 days after the designation of adjacent coastal State pursuant to this section, the Administrator shall transmit a complete copy of the application to the Governor of such State. The Administrator shall not issue a license without consultation with the Governor of each adjacent coastal State which has an approved coastal zone management program in good standing pursuant to the

Coastal Zone Management Act of 1972 (16 U.S.C. 1451 et seq.). If the Governor of such a State has not transmitted his approval or disapproval to the Administrator by the 45th day after public hearings on the application is concluded pursuant to section 102(g) of this title, such approval shall be conclusively presumed. If the Governor of such a State notifies the Administrator that an application which the Governor would otherwise approve pursuant to this paragraph is inconsistent in some respect with the State's coastal zone management program, the Administrator shall condition the license granted so as to make it consistent with such State program.

(2) Any adjacent coastal State which does not have an approved coastal zone management program in good standing, and any other interested State, shall have the opportunity to make its views known to, and to have them given full consideration by, the Administrator regarding the location, construction, and operation of an ocean thermal energy conversion facility or plantship.

Agreement or compact between States.

(c) The consent of Congress is given to 2 or more States to negotiate and enter into agreements or compacts, not in conflict with any law or treaty of the United States, (1) to apply for a license for the ownership, construction, and operation of an ocean thermal energy conversion facility or plantship or for the transfer of such a license, and (2) to establish such agencies, joint or otherwise, as are deemed necessary or appropriate for implementing and carrying out the provisions of any such agreement or compact. Such agreement or compact shall be binding and obligatory upon any State or other party thereto without further approval by the Congress.

42 USC 9116.

SEC. 106. DILIGENCE REQUIREMENTS.

Regulations.

(a) The Administrator shall promulgate regulations requiring each licensee to pursue diligently the construction and operation of the ocean thermal energy conversion facility or plantship to which the license applies.

License termination.

(b) If the Administrator determines that a licensee is not pursuing diligently the construction and operation of the ocean thermal energy conversion facility or plantship to which the license applies, or that the project has apparently been abandoned, the Administrator shall cause proceedings to be instituted under section 111 of this title to terminate the license.

42 USC 9117.

SEC. 107. PROTECTION OF THE ENVIRONMENT.

Environmental assessment program.

(a) The Administrator shall initiate a program to assess the effects on the environment of ocean thermal energy conversion facilities and plantships. The program shall include baseline studies of locations where ocean thermal energy conversion facilities or plantships are likely to be sited or operated; and research; and monitoring of the effects of ocean thermal energy conversion facilities and plantships in actual operation. The purpose of the program shall be to assess the environmental effects of individual ocean thermal energy facilities and plantships, and to assess the magnitude of any cumulative environmental effects of large numbers of ocean thermal energy facilities and plantships.

(b) The program shall be designed to determine, among other things—

(1) any short-term and long-term effects on the environment which may occur as a result of the operation of ocean thermal energy conversion facilities and plantships;

(2) the nature and magnitude of any oceanographic, atmospheric, weather, climatic, or biological changes in the environment which may occur as a result of deployment and operation of large numbers of ocean thermal energy conversion facilities and plantships;

(3) the nature and magnitude of any oceanographic, biological or other changes in the environment which may occur as a result of the operation of electric transmission cables and equipment located in the water column or on or in the seabed, including the hazards of accidentally severed transmission cables; and

(4) whether the magnitude of one or more of the cumulative environmental effects of deployment and operation of large numbers of ocean thermal energy conversion facilities and plantships requires that an upper limit be placed on the number or total capacity of such facilities or plantships to be licensed under this Act for simultaneous operation, either overall or within specific geographic areas.

Plan submittal to Congress.

(c) Within 180 days after enactment of this Act, the Administrator shall prepare a plan to carry out the program described in subsections (a) and (b) of this section, including necessary funding levels for the next 5 fiscal years, and submit the plan to the Congress.

(d) The program established by subsections (a) and (b) of this section shall be reduced to the minimum necessary to perform baseline studies and to analyze monitoring data, when the Administrator determines that the program has resulted in sufficient knowledge to make the determinations enumerated in subsection (b) of this section with an acceptable level of confidence.

Environmental impact statement.

(e) The issuance of any license for ownership, construction, and operation of an ocean thermal energy conversion facility or plantship shall be deemed to be a major Federal action significantly affecting the quality of the human environment for purposes of section 102(2)(C) of the National Environmental Policy Act of 1969 (42 U.S.C. 4332(2)(C)). For all timely applications covering proposed facilities in a single application area, and for each application relating to a proposed plantship, the Administrator shall, pursuant to such section 102(2)(C) and in cooperation with other involved Federal agencies and departments, prepare a single environmental impact statement, which shall fulfill the requirement of all Federal agencies in carrying out their responsibilities pursuant to this Act to prepare an environmental impact statement. Each such draft environmental impact statement relating to proposed facilities shall be prepared and published within 180 days after notice of the initial application has been published pursuant to section 102(d) of this title. Each such draft environmental impact statement relating to a proposed plantship shall be prepared and published within 180 days after notice of the application has been published pursuant to section 102(d) of this title. Each final environmental impact statement shall be published not later than 90 days following the date on which public hearings are concluded pursuant to section 102(g) of this title. The Administrator may extend the deadline for publication of a specific draft or final environmental impact statement to a later specified time for good cause shown in writing.

Ante, p. 979.

Hearings.

Vessel or floating craft.

(f) An ocean thermal energy conversion facility or plantship licensed under this title shall be deemed not to be a "vessel or other floating craft" for the purposes of section 502(12)(B) of the Federal Water Pollution Control Act of 1972 (33 U.S.C. 1362(12)(B)).

42 USC 9118.

SEC. 108. MARINE ENVIRONMENTAL PROTECTION AND SAFETY OF LIFE AND PROPERTY AT SEA.

(a) The Secretary of the department in which the Coast Guard is operating shall, subject to recognized principles of international law, prescribe by regulation and enforce procedures with respect to any ocean thermal energy conversion facility or plantship licensed under this Act, including, but not limited to, rules governing vessel movement, procedures for transfer of materials between such a facility or plantship and transport vessels, designation and marking of anchorage areas, maintenance, law enforcement, and the equipment, training, and maintenance required (1) to promote the safety of life and property at sea, (2) to prevent pollution of the marine environment, (3) to clean up any pollutants which may be discharged, and (4) to otherwise prevent or minimize any adverse impact from the construction and operation of such ocean thermal energy conversion facility or plantship.

Regulations.

(b) The Secretary of the department in which the Coast Guard is operating shall issue and enforce regulations, subject to recognized principles of international law, with respect to lights and other warning devices, safety equipment, and other matters relating to the promotion of safety of life and property on any ocean thermal energy conversion facility or plantship licensed under this Act.

(c) Whenever a licensee fails to mark any component of such an ocean thermal energy conversion facility or plantship in accordance with applicable regulations, the Secretary of the department in which the Coast Guard is operating shall mark such components for the protection of navigation, and the licensee shall pay the cost of such marking.

Safety zone.

(d)(1) Subject to recognized principles of international law and after consultation with the Secretary of Commerce, the Secretary of the Interior, the Secretary of State, and the Secretary of Defense, the Secretary of the department in which the Coast Guard is operating shall designate a zone of appropriate size around and including any ocean thermal energy conversion facility licensed under this Act and may designate such a zone around and including any ocean thermal energy conversion plantship licensed under this Act for the purposes of reorganizational safety and protection of the facility or plantship. The Secretary of the department in which the Coast Guard is operating shall by regulation define permitted activities within such zone consistent with the purpose for which it was designated. The Secretary of the department in which the Coast Guard is operating shall, not later than 30 days after publication of notice pursuant to section 102(d) of this title, designate such safety zone with respect to any proposed ocean thermal energy conversion facility or plantship.

Rules and regulations

(2) In addition to any other regulations, the Secretary of the department in which the Coast Guard is operating is authorized, in accordance with this subsection, to establish a safety zone to be effective during the period of construction of an ocean thermal energy conversion facility or plantship licensed under this Act, and to issue rules and regulations relating thereto.

Regulations, enforcement and compliance.

(e)(1) The Secretary of the department in which the Coast Guard is operating shall promulgate and enforce regulations specified in paragraph (2) of this subsection and such other regulations as he deems necessary concerning the documentation, design, construction, alteration, equipment, maintenance, repair, inspection, certification, and manning of ocean thermal energy conversion facilities and plantships. In addition to other requirements prescribed under those regulations, the Secretary of the department in which the Coast Guard is operating may require compliance with those vessel documentation, inspection, and manning laws which he determines to be appropriate.

Facility or plantship requirements. Regulations.

(2) Within 1 year after the date of enactment of this Act, the Secretary of the department in which the Coast Guard is operating shall promulgate regulations under paragraph (1) of this subsection which require that any ocean thermal energy conversion facility or plantship—

(A) be documented;

(B) comply with minimum standards of design, construction, alteration, and repair; and

(C) be manned or crewed by United States citizens or aliens lawfully admitted to the United States for permanent residence, unless—

(i) there is not a sufficient number of United States citizens, or aliens lawfully admitted to the United States for permanent residence, qualified and available for such work, or

(ii) the President makes a specific finding, with respect to the particular vessel, platform, or moored or standing structure, that application of this requirement would not be consistent with the national interest.

(3) For the purposes of the documentation laws, for which compliance is required under paragraph (1) of this subsection, ocean thermal energy conversion facilities and plantships shall be deemed to be vessels and, if documented, vessels of the United States for the purposes of the Ship Mortgage Act, 1920 (46 U.S.C. 911-984).

(f) Subject to recognized principles of international law, the Secretary of the department in which the Coast Guard is operating shall promulgate and enforce such regulations as he deems necessary to protect navigation in the vicinity of a vessel engaged in the installation, repair, or maintenance of any submarine electric transmission cable or equipment, and to govern the markings and signals used by such a vessel.

42 USC 9119.

SEC. 109. PREVENTION OF INTERFERENCE WITH OTHER USES OF THE HIGH SEAS.

(a) Each license shall include such conditions as may be necessary and appropriate to ensure that construction and operation of the ocean thermal energy conversion facility or plantship are conducted with reasonable regard for navigation, fishing, energy production, scientific research, or other uses of the high seas, either by citizens of the United States or by other nations in their exercise of the freedoms of the high seas as recognized under the Convention of the High Seas and the general principles of international law.

Regulations.

(b) The Administrator shall promulgate regulations specifying under what conditions and in what circumstances the thermal plume of an ocean thermal energy conversion facility or plantship licensed under this Act will be deemed—

(1) to impinge on so as to degrade the thermal gradient used by another ocean thermal energy conversion facility or plantship, or

(2) to impinge on so as to adversely affect the territorial sea or area of natural resource jurisdiction, as recognized by the United States, of any other nation.

Such regulations shall also provide for the Administrator to mediate or arbitrate any disputes among licensees regarding the extent to which the thermal plume of one licensee's facility or plantship impinges on the operation of another licensee's facility or plantship.

(3) Except in a situation involving force majeure, a licensee of an ocean thermal energy conversion facility or plantship shall not permit a vessel, registered in or flying the flag of a foreign state, to call at, load or unload cargo at, or otherwise utilize such a facility or plantship licensed under this Act unless (A) the foreign state involved has agreed, by specific agreement with the United States, to recognize the jurisdiction of the United States over the vessel and its personnel, in accordance with the provisions of this Act, while the vessel is located within the safety zone, and (B) the vessel owner or operator has designated an agent in the United States for receipt of service of process in the event of any claim or legal proceeding resulting from activities of the vessel or its personnel while located within such a safety zone.

Regulations, enforcement.

(c) The Secretary of the department in which the Coast Guard is operating shall promulgate, after consultation with the Administrator, and shall enforce, regulations governing the movement and navigation of ocean thermal energy conversion plantships licensed under this Act to ensure that the thermal plume of such an ocean thermal energy conversion plantship does not unreasonably impinge on so as to degrade the thermal gradient used by the operation of any other ocean thermal energy conversion plantship or facility except in case of force majeure or with the consent of owner of the other such plantship or facility, and to ensure that the thermal plume such of an ocean thermal energy conversion plantship does not impinge on so as to adversely affect the territorial sea or area of national resource jurisdiction, as recognized by the United States, of any other nation unless the Secretary of State has approved such impingment after consultation with such nation.

42 USC 9120.

SEC. 110. MONITORING OF LICENSEES' ACTIVITIES.

Each license shall require the licensee—

(1) to allow the Administrator to place appropriate Federal officers or employees aboard the ocean thermal energy conversion facility or plantship to which the license applies, at such times and to such extent as the Administrator deems reasonable and necessary to assess compliance with any condition or regulation applicable to the license, and to report to the Administrator whenever such officers or employees have reason to believe there is a failure to comply;

(2) to cooperate with such officers and employees in the performance of monitoring functions; and

(3) to monitor the environmental effects, if any, of the operation of the ocean thermal energy conversion facility or plantship in accordance with regulations issued by the Administrator, and to submit such information as the Administrator finds to be necessary and appropriate to assess environmental impacts and to develop and evaluate mitigation methods and possibilities.

42 USC 9121.

SEC. 111. SUSPENSION, REVOCATION, OR TERMINATION OF LICENSE.

(a) Whenever a licensee fails to comply with any applicable provision of this Act or any applicable rule, regulation, restriction, or condition issued or imposed by the Administrator under the authority of this Act, the Attorney General, at the request of the Administrator, shall file an action in the appropriate United States district court to—

(1) suspend the license; or

(2) if such failure is knowing and continues for a period of 30 days after the Administrator mails notification of such failure by registered letter to the licensee at his record post office address, revoke such license.

No proceeding under this section is necessary if the license, by its terms, provides for automatic suspension or termination upon the occurrence of a fixed or agreed upon condition, event, or time.

(b) If the Administrator determines that immediate suspension of the construction or operation of an ocean thermal energy conversion facility or plantship or any component thereof is necessary to protect public health and safety or to eliminate imminent and substantial danger to the environment established by any treaty or convention, the Administrator may order the licensee to cease or alter such construction or operation pending the completion of a judicial proceeding pursuant to subsection (a) of this section.

42 USC 9122.

SEC. 112. RECORDKEEPING AND PUBLIC ACCESS TO INFORMATION.

Reports.

(a) Each licensee shall establish and maintain such records, make such reports, and provide such information as the Administrator, after consultation with other interested Federal departments and agencies, shall by regulation prescribe to carry out the provisions of this Act. Each licensee shall submit such reports and shall make available such records and information as the Administrator may request.

Confidential information.

(b) Any information reported to or collected by the Administrator under this Act which is exempt from disclosure pursuant to section 552(b)(4) of title 5, United States Code (relating to trade secrets and confidential commercial and financial information), shall not—

(1) be publicly disclosed by the Administrator or by any other officer or employee of the United States, unless the Administrator has—

(A) determined that the disclosure is necessary to protect the public health or safety or the environment against an unreasonable risk of injury, and

(B) notified the person who submitted the information 10 days before the disclosure is to be made, unless the delay resulting from such notice would be detrimental to the public health or safety or the environment, or

(2) be otherwise disclosed except—

(A)(i) to other Federal and adjacent coastal State government departments and agencies for official use,

(ii) to any committee of the Congress of appropriate jurisdiction, or

(iii) pursuant to court order, and

(B) when the administrator has taken appropriate steps to inform the recipient of the confidential nature of the information.

42 USC 9123.

SEC. 113. RELINQUISHMENT OR SURRENDER OF LICENSE.

(a) Any licensee may at any time, without penalty, surrender to the Administrator a license issued to him, or relinquish to the Administrator, in whole or in part, any right to conduct construction or operation of an ocean thermal energy conversion facility or plantship, including part or all of any right of way which may have been granted in conjunction with such license: *Provided*, That such surrender or relinquishment shall not relieve the licensee of any obligation or liability established by this or any other Act, or of any obligation or liability for actions taken by him prior to such surrender or relin-

Liability.

quishment, or during disposal or removal of any components required to be disposed of or removed pursuant to this Act.

Right of way.

(b) If part or all of a right of way which is relinquished, or for which the license is surrendered, to the Administrator pursuant to subsection (a) of this section contains an electric transmission cable or pipeline which is used in conjunction with another license for an ocean thermal energy conversion facility, the Administrator shall allow the other licensee an opportunity to add such right of way to his license before informing the Secretary of the Interior that the right of way has been vacated.

42 USC 9124.

SEC. 114. CIVIL ACTIONS.

(a) Except as provided in subsection (b) of this section, any person having a valid legal interest which is or may be adversely affected may commence a civil action for equitable relief on his own behalf in the United States District Court for the District of Columbia whenever such action constitutes a case or controversy—

(1) against any person who is alleged to be in violation of any provision of this Act or any regulation or condition of a license issued pursuant to this Act; or

(2) against the Administrator where there is alleged a failure of the Administrator to perform any act or duty under this Act which is not discretionary.

Suits.

In suits brought under this Act, the district courts of the United States shall have jurisdiction, without regard to the amount in controversy or the citizenship of the parties, to enforce any provision of this Act or any regulation or term or condition of a license issued pursuant to this Act, or to order the Administrator to perform such act or duty, as the case may be.

(b) No civil action may be commenced—

(1) under subsection (a)(1) of this section—

(A) prior to 60 days after the plaintiff has given notice of the violation to the Administrator and to any alleged violator; or

(B) if the Administrator or the Attorney General has commenced and is diligently prosecuting a civil or criminal action with respect to such matters in a court of the United States, but in any such action any person may intervene as a matter of right; or

(2) under subsection (a)(2) of this section prior to 60 days after the plaintiff has given notice of such action to the Administrator.

Notice.

Notice under this subsection shall be given in such a manner as the Administrator shall prescribe by regulation.

(c) In any action under this section, the Administrator or the Attorney General, if not a party, may intervene as a matter of right.

Litigation costs.

(d) The court, in issuing any final order in any action brought pursuant to subsection (a) of this section, may award costs of litigation (including reasonable attorney and expert witness fees) to any party whenever the court determines that such an award is appropriate.

(e) Nothing in this section shall restrict any right which any person or class of persons may have under any statute or common law to seek enforcement or to seek any other relief.

42 USC 9125.

SEC. 115. JUDICIAL REVIEW.

Any person suffering legal wrong, or who is adversely affected or aggrieved by the Administrator's decision to issue, transfer, modify, renew, suspend, or terminate a license may, not later than 60 days after such decision is made, seek judicial review of such decision in the United States Court of Appeals for the District of Columbia. A person shall be deemed to be aggrieved by the Administrator's decision within the meaning of this Act if he—

(1) has participated in the administrative proceedings before the Administrator (or if he did not so participate, he can show that his failure to do so was caused by the Administrator's failure to provide the required notice); and

(2) is adversely affected by the Administrator's action.

42 USC 9126.

SEC. 116. TEST PLATFORMS AND COMMERCIAL DEMONSTRATION OCEAN THERMAL ENERGY CONVERSION FACILITY OR PLANTSHIP.

(a) The provisions of this title shall not apply to any test platform which will not operate as an ocean thermal energy conversion facility or platform after conclusion of the testing period.

(b) The provisions of this title shall not apply to ownership, construction, or operation of any ocean thermal energy conversion facility or plantship which the Secretary of Energy has designated in writing as a demonstration project for the development of alternative energy sources for the United States which is conducted by, participated in, or approved by the Department of Energy. The Secretary of Energy, after consultation with the Administrator, shall require such demonstration projects to abide by as many of the substantive requirements of this title as he deems to be practicable without damaging the nature of or unduly delaying such projects.

42 USC 9127.

SEC. 117. PERIODIC REVIEW AND REVISION OF REGULATIONS.

Review results.

Post, p. 999.

The Administrator and the Secretary of the department in which the Coast Guard is operating shall periodically, at intervals of not more than every 3 years, and in consultation with the Secretary of Energy, review any regulations promulgated pursuant to the provisions of this title to determine the status and impact of such regulations on the continued development, evolution, and commercialization of ocean thermal energy conversion technology. The results of each such review shall be included in the next annual report required by section 405. The Administrator and such Secretary are authorized and directed to promulgate any revisions to the then effective regulations as are deemed necessary and appropriate based on such review, to ensure that any regulations promulgated pursuant to the provisions of this title do not impede such development, evolution, and commercialization of such technology. Additionally, the Secretary of Energy is authorized to propose, based on such review, such revisions for the same purpose. The Administrator or such Secretary, as appropriate, shall have exclusive jurisdiction with respect to any such proposal by the Secretary of Energy and, pursuant to applicable procedures, shall consider and take final action on any such proposal in an expeditious manner. Such consideration shall include at least one informal hearing pursuant to the procedures in section 553 of title 5, United States Code.

Proposals by Secretary of Energy.

Hearing.

TITLE II—MARITIME FINANCING FOR OCEAN THERMAL ENERGY CONVERSION

42 USC 9141.

SEC. 201. DETERMINATIONS UNDER THE MERCHANT MARINE ACT, 1936.

(a)(1) For the purposes of section 607 of the Merchant Marine Act, 1936 (46 U.S.C. 1177), any ocean thermal energy conversion facility or plantship licensed pursuant to this Act, and any vessel providing shipping service to or from such an ocean thermal energy conversion

facility or plantship, shall be deemed to be a vessel operated in the foreign commerce of the United States.

(2) The provisions of paragraph (1) of this subsection shall apply for taxable years beginning after December 31, 1981.

(b) For the purposes of the Merchant Marine Act, 1936 (46 U.S.C. 1177 et seq.) any vessel documented under the laws of the United States and used in providing shipping service to or from any ocean thermal energy conversion facility or plantship licensed pursuant to the provisions of this Act shall be deemed to be used in, and used in an essential service in, the foreign commerce or foreign trade of the United States, as defined in section 905(a) of the Merchant Marine Act, 1936 (46 U.S.C. 1244(a)).

SEC. 202. AMENDMENTS TO TITLE XI OF THE MERCHANT MARINE ACT, 1936.

(a) Section 1101 of the Merchant Marine Act, 1936 (46 U.S.C. 1271), is amended—

(1) in subsection (b) by striking "and" immediately before "dredges" and inserting in lieu thereof a comma, and by inserting immediately after "dredges" the following: "and ocean thermal energy conversion facilities or plantships",

(2) in subsection (g) by striking "and" after the semicolon,

(3) in subsection (h) by striking "equipping" and inserting in lieu thereof "equipping and", and

(4) by adding at the end thereof a new subsection (i) to read as follows:

Definition.

"(i) The term 'ocean thermal energy conversion facility or plantship' means any at-sea facility or vessel, whether mobile, floating unmoored, moored, or standing on the seabed, which uses temperature differences in ocean water to produce electricity or another form of energy capable of being used directly to perform work, and includes any equipment installed on such facility or vessel to use such electricity or other form of energy to produce, process, refine, or manufacture a product, and any cable or pipeline used to deliver such electricity, freshwater, or product to shore, and all other associated equipment and appurtenances of such facility or vessel, to the extent they are located seaward of the highwater mark.".

(b) Section 1104(a)(1) of the Merchant Marine Act, 1936 (46 U.S.C. 1274(a)(1)), is amended by striking "or (E)" and inserting in lieu thereof "(E) as an ocean thermal energy conversion facility or plantship; or (F)".

(c) Section 1104(b)(2) of the Merchant Marine Act, 1936 (46 U.S.C. 1274(b)(2)), is amended by striking "vessel;" and inserting in lieu thereof "vessel: *Provided further,* That in the case of an ocean thermal energy conversion facility or plantship which is constructed without the aid of construction-differential subsidy, such obligations may be in an aggregate principal amount which does not exceed 87½ percent of the actual cost or depreciated actual cost of the facility or plantship;".

SEC. 203. OTEC DEMONSTRATION FUND.

(a) Title XI of the Merchant Marine Act, 1936 (46 U.S.C. 1271–1279b) is further amended by adding at the end thereof a new section 1110 to read as follows:

Guarantees.
46 USC 1279c.
46 USC 1273.

"SEC. 1110. (a) Pursuant to the authority granted under section 1103(a) of this title, the Secretary of Commerce, upon such terms as he shall prescribe, may guarantee or make a commitment to guarantee, payment of the principal of and interest on an obligation which aids in financing, including reimbursement of an obligor for expenditures previously made for, construction, reconstruction, or reconditioning of a commercial demonstration ocean thermal energy conversion facility or plantship owned by citizens of the United States. Guarantees or commitments to guarantee under this subsection shall be subject to all the provisos, requirements, regulations, and procedures which apply to guarantees or commitments to guarantee made pursuant to section 1104(a)(1) of this title, except that—

46 USC 1274.
Exceptions.

"(1) no guarantees or commitments to guarantee may be made by the Secretary of Commerce under this subsection before October 1, 1981;

"(2) the provisions of subsection (d) of section 1104 of this title shall apply to guarantees or commitments to guarantee for that portion of a commercial demonstration ocean thermal energy conversion facility or plantship not to be supported with appropriated Federal funds;

"(3) guarantees or commitments to guarantee made pursuant to this section may be in an aggregate principal amount which does not exceed 87½ percent of the actual cost or depreciated actual cost of the commercial demonstration ocean thermal energy conversion facility or plantship: *Provided,* That, if the commercial demonstration ocean thermal energy conversion facility or plantship is supported with appropriated Federal funds, such guarantees or commitments to guarantee may not exceed 87½ percent of the aggregate principal amount of that portion of the actual cost or depreciated actual cost for which the obligor has an obligation to secure financing in accordance with the terms of the agreement between the obligor and the Department of Energy or other Federal agency; and

"(4) the provisions of this section may be used to guarantee obligations for a total of not more than 5 separate commercial demonstration ocean thermal energy conversion facilities and plantships or a demonstrated 400 megawatt capacity, whichever comes first.

"(b) A guarantee or commitment to guarantee shall not be made under this section unless the Secretary of Energy, in consultation with the Secretary of Commerce, certifies to the Secretary of Commerce that, for the ocean thermal energy conversion facility or plantship for which the guarantee or commitment to guarantee is sought, there is sufficient guarantee of performance and payment to lower the risk to the Federal Government to a level which is reasonable. The Secretary of Energy must base his considerations on the following: (1) the successful demonstration of the technology to be used in such facility at a scale sufficient to establish the likelihood of technical and economic viability in the proposed market; and (2) the need of the United States to develop new and renewable sources of energy and the benefits to be realized from the construction and successful operation of such facility or plantship.

OTEC Demonstration Fund.

"(c) A special subaccount in the Federal Ship Financing Fund, to be known as the OTEC Demonstration Fund, shall be established on October 1, 1981. The OTEC Demonstration Fund shall be used for obligation guarantees authorized under this section which do not qualify under other sections of this title. Except as specified otherwise in this section, the operation of the OTEC Demonstration Fund shall be identical with that of the parent Federal Ship Financing Fund: except that, notwithstanding the provisions of section 1104(g), 46 USC 1274.
(1) all moneys received by the Secretary pursuant to sections 1101 through 1107 of this title with respect to guarantees or commitments 46 USC 1271–1279.

Notes or obligations. 46 USC 1275.

to guarantee made pursuant to this section shall be deposited only in the OTEC Demonstration Fund, and (2) whenever there shall be outstanding any notes or other obligations issued by the Secretary of Commerce pursuant to section 1105(d) of this title with respect to the OTEC Demonstration Fund, all moneys received by the Secretary of Commerce pursuant to sections 1101 through 1107 of this title with respect to ocean thermal energy conversional facilities or plantships shall be deposited in the OTEC Demonstration Fund. Assets in the OTEC Demonstration Fund may at any time be transferred to the parent fund whenever and to the extent that the balance thereof exceeds the total guarantees or commitments to guarantee made pursuant to this section then outstanding, plus any notes or other obligations issued by the Secretary of Commerce pursuant to section 1105(d) of this title with respect to the OTEC Demonstration Fund. The Federal Ship Financing Fund shall not be liable for any guarantees or commitments to guarantee issued pursuant to this section. The aggregate unpaid principal amount of the obligations guaranteed with the backing of the OTEC Demonstration Fund and outstanding at any one time shall not exceed $2,000,000,000.

46 USC 1271-1279.

Transfer of assets.

Notes or obligations. 46 USC 1275.

"(d) The provisions of section 1105(d) of this title shall apply specifically to the OTEC Demonstration Fund as well as to the Fund: *Provided, however,* That any notes or obligations issued by the Secretary of Commerce pursuant to section 1105(d) of this title with respect to the OTEC Demonstration Fund shall be payable solely from proceeds realized by the OTEC Demonstration Fund.

Interest.

"(e) The interest on any obligation guaranteed under this section shall be included in gross income for purposes of chapter 1 of the Internal Revenue Code of 1954.".

26 USC 1 *et seq.*

(b)(1) Section 1103(f) of the Merchant Marine Act, 1936 (46 U.S.C. 1273(f)) is amended by striking out "$10,000,000,000." and inserting in lieu thereof "$12,000,000,000, of which $2,000,000,000 shall be limited to obligations pertaining to commercial demonstration ocean thermal energy conversion facilities or plantships guaranteed pursuant to section 1110 of this title.".

Ante, p. 992. Effective date. 46 USC 1273 note.

(2) The amendment made by paragraph (1) of this subsection shall take effect October 1, 1981.

TITLE III—ENFORCEMENT

42 USC 9151.

SEC. 301. PROHIBITED ACTS.

It is unlawful for any person who is a United States citizen or national, or a foreign national on board an ocean thermal energy conversion facility or plantship or other vessel documented or numbered under the laws of the United States, or who is subject to the jurisdiction of the United States by an international agreement to which the United States is a party—

(1) to violate any provision of this Act, or any rule, regulation, or order issued pursuant to this Act, or any term or condition of any license issued to such person pursuant to this Act;

(2) to refuse to permit any Federal officer or employee authorized to monitor or enforce the provisions of sections 110 and 303 of this Act to board an ocean thermal energy conversion facility or plantship or any vessel documented or numbered under the laws of the United States, for purposes of conducting any search or inspection in connection with the monitoring or enforcement of this Act or any rule, regulation, order, term, or condition referred to in paragraph (1) of this section;

(3) to forcibly assault, resist, oppose, impede, intimidate, or interfere with any such authorized officer or employee in the conduct of any search or inspection described in paragraph (2) of this section;

(4) to resist a lawful arrest for any act prohibited by this section; or

(5) to interfere with, delay, or prevent, by any means, the apprehension or arrest of another person subject to this section knowing that the other person has committed any act prohibited by this section.

42 USC 9152.

SEC. 302. REMEDIES AND PENALTIES.

Orders, issuance and enforcement.

(a)(1) The Administrator or his delegate shall have the authority to issue and enforce orders during proceedings brought under this Act. Such authority shall include the authority to issue subpenas, administer oaths, compel the attendance and testimony of witnesses and the production of books, papers, documents, and other evidence, to take depositions before any designated individual competent to administer oaths, and to examine witnesses.

(2) Whenever on the basis of any information available to him the Administrator finds that any person subject to section 301 of this title is in violation of any provision of this Act or any rule, regulation, order, license, or term or condition thereof, or other requirements under this Act, he may issue an order requiring such person to comply with such provision or requirement, or bring a civil action in accordance with subsection (b) of this section.

(3) Any compliance order issued under this subsection shall state with reasonable specificity the nature of the violation and a time for compliance, not to exceed 30 days, which the Administrator determines is reasonable, taking into account the seriousness of the violation and any good faith efforts to comply with applicable requirements.

(b)(1) Upon a request by the Administrator, the Attorney General shall commence a civil action for appropriate relief, including a permanent or temporary injunction, any violation for which the Administrator is authorized to issue a compliance order under subsection (a)(2) of this section.

(2) Upon a request by the Administrator, the Attorney General shall bring an action in an appropriate district court of the United States for equitable relief to redress a violation, by any person subject to section 301 of this title, of any provision of this Act, any regulation issued pursuant to this Act, or any license condition.

Liability.

(c)(1) Any person who is found by the Administrator, after notice and an opportunity for a hearing in accordance with section 554 of title 5, United States Code, to have committed an act prohibited by section 301 of this title shall be liable to the United States for a civil penalty, not to exceed $25,000 for each violation. Each day of a continuing violation shall constitute a separate violation. The amount of such civil penalty shall be assessed by the Administrator, or his designee, by written notice. In determining the amount of such penalty, the Administrator shall take into account the nature, circumstances, extent and gravity of the prohibited acts committed and, with respect to the violator, the degree of culpability, any history of prior offenses, ability to pay, and such other matters as justice may require.

Review.

(2) Any person against whom a civil penalty is assessed under paragraph (1) of this subsection may obtain a review thereof in the appropriate court of the United States by filing a notice of appeal in

such court within 30 days from the date of such order and by simultaneously sending a copy of such notice by certified mail to the Administrator. The Administrator shall promptly file in such court a certified copy of the record upon which such violation was found or such penalty imposed, as provided in section 2112 of title 28, United States Code. The findings and order of the Administrator shall be set aside by such court if they are not found to be supported by substantial evidence, as provided in section 706(2) of title 5, United States Code.

Filing of certified copy.

Assessment, failure to pay.

(3) If any person subject to section 301 fails to pay an assessment of a civil penalty against him after it has become final, or after the appropriate court has entered final judgment in favor of the Administrator, the Administrator shall refer the matter to the Attorney General of the United States, who shall recover the amount assessed in any appropriate court of the United States. In such action, the validity and appropriateness of the final order imposing the civil penalty shall not be subject to review.

Review.

(4) The Administrator may compromise, modify, or remit, with or without conditions, any civil penalty which is subject to imposition or which has been imposed under this subsection.

(d)(1) Any person subject to section 301 of this title is guilty of an offense if he willfully commits any act prohibited by such section.

(2) Any offense, other than an offense for which the punishment is prescribed by section 103 of this Act, is punishable by a fine of not more than $75,000 for each day during which the violation continues. Any offense described in paragraphs (2), (3), (4), and (5) of section 301 is punishable by the fine or imprisonment for not more than 6 months, or both. If, in the commission of any offense, the person subject to section 301 uses a dangerous weapon, engages in conduct that causes bodily injury to any Federal officer or employee, or places any Federal officer or employee in fear of imminent bodily injury, the offense is punishable by a fine of not more than $100,000 or imprisonment for not more than 10 years, or both.

(e) Any ocean thermal energy conversion facility or plantship licensed pursuant to this Act and any other vessel documented or numbered under the laws of the United States, except a public vessel engaged in noncommercial activities, used in any violation of this Act or of any rule, regulation, order, license, or term or condition thereof, or other requirements of this Act, shall be liable in rem for any civil penalty assessed or criminal fine imposed and may be proceeded against in any district court of the United States having jurisdiction thereof, whenever it shall appear that one or more of the owners, or bareboat charterers, was at the time of the violation a consenting party or privy to such violation.

42 USC 9153.

SEC. 303. ENFORCEMENT.

Responsibility of NOAA Administrator.

(a) Except where a specific section of this Act designates enforcement responsibility, the provisions of this Act shall be enforced by the Administrator. The Secretary of the department in which the Coast Guard is operating shall have exclusive responsibility for enforcement measures which affect the safety of life and property at sea, shall exercise such other enforcement responsibilities with respect to vessels subject to the provisions of this Act as are authorized under other provisions of law, and may, upon the specific request of the Administrator, assist the Administrator in the enforcement of any provision of this Act. The Administrator and the Secretary of the department in which the Coast Guard is operating may, by agreement, on a reimbursable basis or otherwise, utilize the personnel,

services, equipment, including aircraft and vessels, and facilities of any other Federal agency or department, and may authorize officers or employees of other departments or agencies to provide assistance as necessary in carrying out subsection (b) of this section. The Administrator and the Secretary of the department in which the Coast Guard is operating may issue regulations jointly or severally as may be necessary and appropriate to carry out their duties under this section.

(b) To enforce the provisions of this Act on board any ocean thermal energy conversion facility or plantship or other vessel subject to the provisions of this Act, any officer who is authorized by the Administrator or the Secretary of the department in which the Coast Guard is operating may—

(1) board and inspect any vessel which is subject to the provisions of this Act;

(2) search the vessel if the officer has reasonable cause to believe that the vessel has been used or employed in the violation of any provision of this Act;

(3) arrest any person subject to section 301 of this title if the officer has reasonable cause to believe that the person has committed a criminal act prohibited by sections 301 and 302(d) of this title;

(4) seize the vessel together with its gear, furniture, appurtenances, stores, and cargo, used or employed in, or with respect to which it reasonably appears that such vessel was used or employed in, the violation of any provision of this Act if such seizure is necessary to prevent evasion of the enforcement of this Act;

(5) seize any evidence related to any violation of any provision of this Act;

(6) execute any warrant or other process issued by any court of competent jurisdiction; and

(7) exercise any other lawful authority.

(c) Except as otherwise specified in section 115 of this Act, the district courts of the United States shall have exclusive original jurisdiction over any case or controversy arising under the provisions of this Act. Except as otherwise specified in this Act, venue shall lie in any district wherein, or nearest to which, the cause of action arose, or wherein any defendant resides, may be found, or has his principal office. In the case of Guam, and any Commonwealth, territory, or possession of the United States in the Pacific Ocean, the appropriate court is the United States District Court for the District of Guam, except that in the case of American Samoa, the appropriate court is the United States District Court for the District of Hawaii. Any such court may, at any time—

(1) enter restraining orders or prohibitions;

(2) issue warrants, process in rem, or other process;

(3) prescribe and accept satisfactory bonds or other security; and

(4) take such other actions as are in the interest of justice.

(d) For the purposes of this section, the term "vessel" includes an ocean thermal energy conversion facility or plantship, and the term "provisions of this Act" or "provision of this Act" includes any rule, regulation, or order issued pursuant to this Act and any term or condition of any license issued pursuant to this Act. Definitions.

TITLE IV—MISCELLANEOUS PROVISIONS

42 USC 9161.

SEC. 401. EFFECT OF LAW OF THE SEA TREATY.

If the United States ratifies a treaty, which includes provisions with respect to jurisdiction over ocean thermal energy conversion activities, resulting from any United Nations Conference on the Law of the Sea, the Administrator, after consultation with the Secretary of State, shall promulgate any amendment to the regulations promulgated under this Act which is necessary and appropriate to conform such regulations to the provisions of such treaty, in anticipation of the date when such treaty shall come into force and effect for, or otherwise be applicable to, the United States.

42 USC 9162.

SEC. 402. INTERNATIONAL NEGOTIATIONS.

The Secretary of State, in cooperation with the Administrator and the Secretary of the department in which the Coast Guard is operating, shall seek effective international action and cooperation in support of the policy and purposes of this Act and may initiate and conduct negotiations for the purpose of entering into international agreements designed to guarantee noninterference of ocean thermal energy conversion facilities and plantships with the thermal gradients used by other such facilities and plantships, to assure protection of such facilities and plantships and of navigational safety in the vicinity thereof, and to resolve such other matters relating to ocean thermal energy conversion facilities and plantships as need to be resolved in international agreements.

42 USC 9163.

SEC. 403. RELATIONSHIP TO OTHER LAWS.

(a)(1) The Constitution, laws, and treaties of the United States shall apply to an ocean thermal energy conversion facility or plantship licensed under this Act and to activities connected, associated, or potentially interfering with the use or operation of any such facility or plantship, in the same manner as if such facility or plantship were an area of exclusive Federal jurisdiction located within a State. Nothing in this Act shall be construed to relieve, exempt, or immunize any person from any other requirement imposed by Federal law, regulation, or treaty.

(2) Ocean thermal energy conversion facilities and plantships licensed under this Act do not possess the status of islands and have no territorial seas of their own.

(b)(1) Except as may otherwise be provided by this Act, nothing in this Act shall in any way alter the responsibilities and authorities of a State or the United States within the territorial seas of the United States.

(2) The law of the nearest adjacent coastal State to which an ocean thermal energy conversion facility located beyond the territorial sea and licensed under this Act is connected by electric transmission cable or pipeline, now in effect or hereafter adopted, amended, or repealed, is declared to be the law of the United States, and shall apply to such facility, to the extent applicable and not inconsistent with any provision or regulation under this Act or other Federal laws and regulations now in effect or hereafter adopted, amended, or repealed: *Provided, however,* That the application of State taxation laws is not extended hereby outside the seaward boundary of any State. All such applicable laws shall be administered and enforced by the appropriate officers and courts of the United States outside the seaward boundary of any State.

Enforcement.

(c)(1) For the purposes of the customs laws administered by the Secretary of the Treasury, ocean thermal energy conversion facilities and plantships documented under the laws of the United States and licensed under this Act shall be deemed to be vessels.

(2) Except insofar as they apply to vessels documented under the laws of the United States, the customs laws administered by the Secretary of the Treasury shall not apply to any ocean thermal energy conversion facility or plantship licensed under the provisions of this Act, but all foreign articles to be used in the construction of any such facility or plantship, including any component thereof, shall first be made subject to all applicable duties and taxes which would be imposed upon or by reason of their importation if they were imported for consumption in the United States. Duties and taxes shall be paid thereon in accordance with laws applicable to merchandise imported into the customs territory of the United States.

SEC. 404. SUBMARINE ELECTRIC TRANSMISSION CABLE AND EQUIPMENT SAFETY.

42 USC 9164.

Safety standards and regulations.

(a) The Secretary of Energy, in cooperation with other interested Federal agencies and departments, shall establish and enforce such standards and regulations as may be necessary to assure the safe construction and operation of submarine electric transmission cables and equipment subject to the jurisdiction of the United States. Such standards and regulations shall include, but not be limited to, requirements for the use of the safest and best available technology for submarine electric transmission cable shielding, and for the use of automatic switches to shut off electric current in the event of a break in such a cable.

Report to Congress.

(b) The Secretary of Energy, in cooperation with other interested Federal agencies and departments, is authorized and directed to report to the Congress within 60 days after the date of enactment of this Act on appropriations and staffing needed to monitor submarine electric transmission cables and equipment subject to the jurisdiction of the United States so as to assure that they meet all applicable standards for construction, operation, and maintenance.

SEC. 405. ANNUAL REPORT.

42 USC 9165.

Submittal to President of Senate and Speaker of House.

Within 6 months after the end of each of the first 3 fiscal years after the date of enactment of this Act, the Administrator shall submit to the President of the Senate and the Speaker of the House of Representatives a report on the administration of this Act during such fiscal year. Such report shall include, with respect to the fiscal year covered by the report—

(1) a description of progress in implementing this Act;

(2) a list of all licenses issued, suspended, revoked, relinquished, surrendered, terminated, renewed, or transferred; denials of issuance of licenses; and required suspensions and modifications of activities under licenses;

(3) a description of ocean thermal energy conversion activities undertaken pursuant to licenses;

(4) the number and description of all civil and criminal proceedings instituted under title III of this Act, and the current status of such proceedings; and

(5) such recommendations as the Administrator deems appropriate for amending this Act.

42 USC 9166.

SEC. 406. AUTHORIZATION OF APPROPRIATIONS.

There are authorized to be appropriated to the Secretary of Commerce, for the use of the Administrator in carrying out the provisions of this Act, not to exceed $3,000,000 for the fiscal year ending September 30, 1981, not to exceed $3,500,000 for the fiscal year ending September 30, 1982, and not to exceed $3,500,000 for the fiscal year ending September 30, 1983.

42 USC 9167.

SEC. 407. SEVERABILITY.

If any provision of this Act or any application thereof is held invalid, the validity of the remainder of the Act, or any other application, shall not be affected thereby.

Approved August 3, 1980.

LEGISLATIVE HISTORY:

HOUSE REPORT No. 96-994 accompanying H.R. 6154 (Comm. on Merchant Marine and Fisheries).
SENATE REPORT No. 96-721 (Comm. on Commerce, Science, and Transportation).
CONGRESSIONAL RECORD, Vol. 126 (1980):
July 2, considered and passed Senate.
July 21, H.R. 6154 considered and passed House; passage vacated and S. 2492 passed in lieu.
WEEKLY COMPILATION OF PRESIDENTIAL DOCUMENTS, Vol. 16, No. 32:
Aug. 4, Presidential statement.

OCEAN THERMAL ENERGY CONVERSION RESEARCH, DEVELOPMENT, AND DEMONSTRATION ACT

(PL 96-310 – JULY 17, 1980)

Public Law 96-310
96th Congress

An Act

To provide for a research, development, and demonstration program to achieve early technology applications for ocean thermal energy conversion systems, and for other purposes.

July 17, 1980
[H.R. 7474]

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "Ocean Thermal Energy Conversion Research, Development, and Demonstration Act".

Ocean Thermal Energy Conversion Research, Development, and Demonstration Act.
42 USC 9001 note.
42 USC 9001.

FINDINGS AND PURPOSES

SEC. 2. (a) The Congress finds that—

(1) the supply of nonrenewable fuels in the United States is slowly being depleted;

(2) alternative sources of energy must be developed;

(3) ocean thermal energy is a renewable energy resource that can make a significant contribution to the energy needs of the United States;

(4) the technology base for ocean thermal energy conversion has improved over the past two years, and has consequently lowered the technical risk involved in constructing moderate-sized pilot plants with an electrical generating capacity of about ten to forty megawatts;

(5) while the Federal ocean thermal energy conversion program has grown in size and scope over the past several years, it is in the national interest to accelerate efforts to commercialize ocean thermal energy conversion by building pilot and demonstration facilities and to begin planning for the commercial demonstration of ocean thermal energy conversion technology;

(6) a strong and innovative domestic industry committed to the commercialization of ocean thermal energy conversion must be established, and many competent domestic industrial groups are already involved in ocean thermal energy conversion research and development activity; and

(7) consistent with the findings of the Domestic Policy Review on Solar Energy, ocean thermal energy conversion energy can potentially contribute at least one-tenth of quad of energy per year by the year 2000.

(b) Therefore, the purpose of this Act is to accelerate ocean thermal energy conversion technology development to provide a technical base for meeting the following goals:

(1) demonstration by 1986 of at least one hundred megawatts of electrical capacity or energy product equivalent from ocean thermal energy conversion systems;

(2) demonstration by 1989 of at least five hundred megawatts of electrical capacity or energy product equivalent from ocean thermal energy conversion systems;

(3) achievement in the mid-1990's, for the gulf coast region of the continental United States and for islands in the United

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States, its possessions and its territories, an average cost of electricity or energy product equivalent produced by installed ocean thermal energy conversion systems that is competitive with conventional energy sources; and

(4) establish as a national goal ten thousand megawatts of electrical capacity or energy product equivalent from ocean thermal energy conversion systems by the year 1999.

COMPREHENSIVE PROGRAM MANAGEMENT PLAN

42 USC 9002.

SEC. 3. (a)(1) The Secretary is authorized and directed to prepare a comprehensive program management plan for the conduct under this Act of research, development, and demonstration activities consistent with the provisions of sections 4, 5, and 6.

Consultation.

(2) In the preparation of such plan, the Secretary shall consult with the Administrator of the National Oceanic and Atmospheric Administration, the Administrator of the Maritime Administration, the Administrator of the National Aeronautics and Space Administration, and the heads of such other Federal agencies and such public and private organizations as he deems appropriate.

Transmittal to congressional committees.

(b) The Secretary shall transmit the comprehensive program management plan to the Committee on Science and Technology of the House of Representatives and the Committee on Energy and Natural Resources of the Senate within nine months after the date of the enactment of this Act.

(c) The detailed description of the comprehensive plan under this section shall include, but need not be limited to—

(1) the anticipated research, development, and demonstration objectives to be achieved by the program;

(2) the program strategies and technology application and market development plans, including detailed milestone goals to be achieved during the next fiscal year for all major activities and projects;

(3) a five-year implementation schedule for program elements with associated budget and program management resources requirements;

(4) a detailed description of the functional organization of the program management including identification of permanent test facilities and of a lead center responsible for technology support and project management;

(5) the estimated relative financial contributions of the Federal Government and non-Federal participants in the pilot and demonstration projects;

(6) supporting research needed to solve problems which may inhibit or limit development of ocean thermal energy conversion systems; and

(7) an analysis of the environmental, economic, and societal impacts of ocean thermal energy conversion facilities.

Modifications, transmittal to Congress.

(d)(1) Concurrently with the submission of the President's annual budget for each subsequent year, the Secretary shall transmit to the Congress a detailed description of modifications which may be necessary to revise appropriately the comprehensive plan as then in effect, setting forth any changes in circumstances which may have occurred since the plan or the last previous modification thereof was transmitted in accordance with this section.

(2) Such description shall also include a detailed justification of any such changes, a detailed description of the progress made toward achieving the goals of this Act, a statement on the status of inter-

agency cooperation in meeting such goals, any comments on and recommendations for improvements in the comprehensive program management plan made by the Technical Panel established under section 8, and any legislative or other recommendations which the Secretary may have to help attain such goals.

RESEARCH AND DEVELOPMENT

42 USC 9003.

SEC. 4. (a) The Secretary shall initiate research or accelerate existing research in areas in which the lack of knowledge limits development of ocean thermal energy conversion systems in order to achieve the purposes of this Act.

(b) The Secretary shall conduct evaluations, arrange for tests, and disseminate to developers information, data, and materials necessary to support the design efforts undertaken pursuant to section 5. Specific technical areas to be addressed shall include, but not be limited to—

(1) interface requirements between the platform and cold water pipe;

(2) cold water pipe deployment techniques;

(3) heat exchangers;

(4) control system simulation;

(5) stationkeeping requirements; and

(6) energy delivery systems, such as electric cable or energy product transport.

(c) The Secretary shall, for the purpose of performing his reponsibilities pursuant to this Act, solicit proposals and evaluate any reasonable new or improved technology, a description of which is submitted to the Secretary in writing, which could lead or contribute to the development of ocean thermal energy conversion system technology.

PILOT AND DEMONSTRATION PLANTS

42 USC 9004.

SEC. 5. (a) The Secretary is authorized to initiate a program to design, construct, and operate well instrumented ocean thermal energy conversion facilities of sufficient size to demonstrate the technical feasibility and potential economic feasibility of utilizing the various forms of ocean thermal energy conversion to displace non-renewable fuels. To achieve the goals of this section and to facilitate development of a strong industrial basis for the application of ocean thermal energy conversion system technology, at least two independent parallel demonstration projects shall be competitively selected.

(b) The specific goals of the demonstration program shall include at a minimum—

(1) the demonstration of ocean thermal energy conversion technical feasibility through multiple pilot and demonstration plants with a combined capacity of at least one hundred megawatts of electrical capacity or energy product equivalent by the year 1986;

(2) the delivery of baseload electricity to utilities located on land or the production of commercially attractive quantities of energy product; and

(3) the continuous operation of each pilot and demonstration facility for a sufficient period of time to collect and analyze system performance and reliability data.

(c) In providing any financial assistance under this section, the Secretary shall (1) give full consideration to those projects which will provide energy to United States offshore States, its territories, and its possessions and (2) seek satisfactory cost-sharing arrangements when he deems such arrangements to be appropriate.

TECHNOLOGY APPLICATION

Consultation. 42 USC 9005.

SEC. 6 (a) The Secretary shall, in consultation with the Administrator of the National Oceanic and Atmospheric Administration, the Administrator of the Maritime Administration, the Administrator of the National Aeronautics and Space Administration, and the Technical Panel established under section 8, prepare a comprehensive technology application and market development plan that will permit realization of the ten-thousand-megawatt national goal by the year 1999. Such plans shall include at a minimum—

(1) an assessment of those Government actions required to achieve a two-hundred- to four-hundred-megawatt electrical-commercial demonstration of ocean thermal energy conversion systems in time to have industry meet the goal contained in section 2(b)(2) including a listing of those financial, property, and patent right packages most likely to lead to early commercial demonstration at minimum cost to the Federal Government;

(2) an assessment of further Government actions required to permit expansion of the domestic ocean thermal energy conversion industry to meet the goal contained in section 2(b)(3);

(3) an analysis of further Government actions necessary to aid the industry in minimizing and removing any legal and institutional barriers such as the designation of a lead agency; and

(4) an assessment of the necessary Government actions to assist in eliminating economic uncertainties through financial incentives, such as loan guarantees, price supports, or other inducements.

Transmittal to Congress.

(b) The Secretary shall transmit such comprehensive technology application and market development plan to the Congress within three years after the date of enactment of this Act, and update the plan on an annual basis thereafter.

(c) As part of the competitive procurement initiative for design and construction of the pilot and demonstration projects authorized in section 10(c), each respondent shall include in its proposal (1) a plan leading to a full-scale, first-of-a-kind facility based on a proposed demonstration system; and (2) the financial and other contributions the respondent will make toward meeting the national goals.

PROGRAM SELECTION CRITERIA

42 USC 9006.

SEC. 7. The Secretary shall, in fulfilling his responsibilities under this Act, select program activities and set priorities which are consistent with the following criteria:

(1) realization of energy production costs for ocean thermal energy conversion systems that are competitive with costs from conventional energy production systems;

(2) encouragement of projects for which contributions to project costs are forthcoming from private, industrial, utility, or governmental entities for the purpose of sharing with the Federal Government the costs of purchasing and installing ocean thermal energy conversion systems;

(3) promotion of ocean thermal energy conversion facilities for coastal areas, islands, and isolated military institutions which are vulnerable to interruption in the fossil fuel supply;

(4) preference for and priority to persons and domestic firms whose base of operations is in the United States as will assure that the program under this Act promotes the development of a United States domestic technology for ocean thermal energy conversion; and

(5) preference for proposals for pilot and demonstration projects in which the respondents certify their intent to become an integral part of the industrial infrastructure necessary to meet the goals of this Act.

TECHNICAL PANEL

42 USC 9007.

SEC. 8. (a) A Technical Panel of the Energy Research Advisory Board shall be established to advise the Board on the conduct of the ocean thermal energy conversion program.

Membership.

(b)(1) The Technical Panel shall be comprised of such representatives from domestic industry, universities, Government laboratories, financial, environmental and other organizations as the Chairman of the Energy Research Advisory Board deems appropriate based on his assessment of the technical and other qualifications of such representative.

(2) Members of the Technical Panel need not be members of the full Energy Research Advisory Board.

(c) The activities of the Technical Panel shall be in compliance with any laws and regulations guiding the activities of technical and fact-finding groups reporting to the Energy Research Advisory Board.

Review and recommendations.

(d) The Technical Panel shall review and may make recommendations on the following items, among others:

(1) implementation and conduct of the programs established by this Act;

(2) definition of ocean thermal energy conversion system performance requirements for various user applications; and

(3) economic, technological, and environmental consequences of the deployment of ocean thermal energy conversion systems.

Report, submittal to Board.

(e) The Technical Panel shall submit to the Energy Research Advisory Board on at least an annual basis a written report of its findings and recommendations with regard to the program. Such report, shall include at a minimum—

(1) a summary of the Panel's activities for the preceding year;

(2) an assessment and evaluation of the status of the programs mandated by this Act; and

(3) comments on and recommendations for improvements in the comprehensive program management plan required under section 3.

Submittal to Secretary.

(f) After consideration of the Technical Panel report, the Energy Research Advisory Board shall submit such report, together with any comments such Board deems appropriate, to the Secretary.

Cooperation by agency heads.

(g) The heads of the departments, agencies, and instrumentalities of the executive branch of the Federal Government shall cooperate with the Technical Panel in carrying out the requirements of this section and shall furnish to the Technical Panel such information as the Technical Panel deems necessary to carry out this section.

Support.

(h) The Secretary shall provide sufficient staff, funds, and other support as necessary to enable the Technical Panel to carry out the functions described in this section.

DEFINITIONS

42 USC 9008.

SEC. 9. As used in this Act, the term—

(1) "ocean thermal energy conversion" means a method of converting part of the heat from the Sun which is stored in the surface layers of a body of water into electrical energy or energy product equivalent;

(2) "energy product equivalent" means an energy carrier including, but not limited to, ammonia, hydrogen, or molten salts or an energy-intensive commodity, including, but not limited to, electrometals, fresh water, or nutrients for aquaculture; and

(3) "Secretary" means the Secretary of Energy.

AUTHORIZATION FOR APPROPRIATION

42 USC 9009.

SEC. 10. (a) There is hereby authorized to be appropriated to carry out the purposes of this Act the sum of $20,000,000 for operating expenses for the fiscal year ending September 30, 1981, in addition to any amounts authorized to be appropriated in the fiscal year 1981 Authorization Act pursuant to section 660 of Public Law 95-91.

42 USC 7270.

(b) There is hereby authorized to be appropriated to carry out the purposes of this Act the sum of $60,000,000 for operating expenses for the fiscal year ending September 30, 1982.

(c) Funds are hereby authorized to be appropriated for fiscal year 1981 to carry out the purposes of section 5 of this Act for plant and capital equipment as follows:

Project 81-ES-1, ocean thermal energy conversion demostration plants with a combined capacity of at least one hundred megawatts electrical or the energy product equivalent, sites to be determined, conceptual and preliminary design activities only $5,000,000.

(d) Funds are hereby authorized to be appropriated for fiscal year 1982 to carry out the purposes of section 5 of this Act for plant and capital equipment as follows:

Project 81-ES-1, ocean thermal energy conversion demonstration plants with a combined capacity of at least one hundred megawatts electrical or the energy product equivalent, sites to be determined, conceptual and preliminary design activities only $25,000,000.

Approved July 17, 1980.

LEGISLATIVE HISTORY:

HOUSE REPORT No. 96-1092 (Comm. on Science and Technology).
SENATE REPORT No. 96-501 accompanying S. 1830 (Comm. on Energy and Natural Resources).
CONGRESSIONAL RECORD, Vol. 126 (1980):
Jan. 25, S. 1830 considered and passed Senate.
June 16, 17, H.R. 7474 considered and passed House.
June 28, considered and passed Senate, amended.
July 2, House concurred in Senate amendment to the title and concurred in Senate amendment to the text with an amendment; Senate concurred in House amendment.
WEEKLY COMPILATION OF PRESIDENTIAL DOCUMENTS, Vol. 16, No. 29:
July 18, Presidential statement.

Appendix B

OTEC PROGRAM STATUS

The concept of using the temperature differential between warm surface and cold deep ocean waters as a source of energy was first proposed by Jacques D'Arsonval in 1881. In 1930, Georges Claude constructed an open-cycle OTEC power plant off the coast of Cuba, but his experiments were not successful in demonstrating that net electrical power could be produced by the OTEC concept. Minimal interest was given to OTEC as a potential energy resource until 1972, when the declining supply of nonrenewable fuels and increased price of imported oil forced the United States to assess alternative methods for achieving its energy requirements. OTEC funding in the U.S. was initiated in 1972 by the National Science Foundation (NSF) Research Applied to National Needs (RANN) Program. The Ocean Systems Branch of the Department of Energy (DOE) is presently responsible for managing the OTEC Program.

Prior to 1977, OTEC program development centered primarily on component research and system feasibility studies. At that time, a body of influential opinion held the OTEC concept to be, at best, economically unsound and, at worst, unworkable. Results received from DOE-funded studies after 1977 showed that OTEC engineering problems were surmountable and that the fundamental theoretical calculations were sufficiently sound to warrant construction of small-scale test platforms. The DOE and private industries initiated the development of several OTEC test platforms, which have recently begun operation. A brief summary of the status of these projects is presented in the following subsections.

The DOE OTEC program is proceeding toward its goal of demonstrating the technological, economic, and environmental feasibility of OTEC power plants through interrelated subprograms of strategy and definition planning, engineering development, and commercial demonstration. The DOE OTEC program will culminate in the demonstration of a 40-MWe (net) pilot plant by 1986. The OTEC Pilot Plant program is briefly described in section B.4.

B.1 Mini-OTEC

Mini-OTEC is a modified U.S. Navy barge which became the world's first successful closed-cycle OTEC plant to produce net energy at sea. The first deployment of Mini-OTEC occurred near Ke-ahole Point, Hawaii and was a joint venture between the State of Hawaii, Lockheed Missiles and Space Company (LMSC), Dillingham Corporation, and other participants. The general objectives of the Mini-OTEC project were to:

- Develop an operating at-sea OTEC system
- Gain "real-world" operating experience on an OTEC system
- Provide a subsystem, component, and technology facility that can be used for test purposes
- Expand public awareness of the OTEC potential.

The Mini-OTEC power plant was designed and assembled by LMSC, the titanium heat exchangers were loaned by Alfa Laval Thermal of Sweden, and Dillingham Corporation modified the barge and installed the cold-water pipe. Offsite construction of heat exchangers and other plant components began in late 1978, and shipyard modifications to the barge began in January 1979. The barge was deployed to the mooring site off Ke-ahole Point in July 1979 and the first successful production of net OTEC power occurred on 2 August 1979. Mini-OTEC produced an average of 18 kWe net electrical power from a seawater temperature differential of 21°C. Plant operation was concluded in November 1979, after operating for a total of approximately 620 hours.

Plans are being made by the DOE to redeploy Mini-OTEC and demonstrate either the transmission of OTEC-produced electricity to shore through a submarine transmission cable, or the production of energy-intensive products, such as hydrogen or ammonia.

B.2 OTEC-1

OTEC-1, a converted T-2 tanker renamed the *Ocean Energy Converter*, is a test platform from which various OTEC plant components can be tested at sea. The primary objectives of the OTEC-1 project are to operate and test modular components, without generating electricity, to evaluate:

- Engineering designs and construction materials,
- Heat exchanger performance,
- Corrosion and biofouling control methods, and
- Potential environmental impacts.

OTEC-1 was deployed in September 1980, and began operating in January 1981. The first deployment, curtailed to six months as a result of funding constraints, evaluated the titanium tube-in-shell heat exchanger design. After refitting, OTEC-1 will be redeployed in 1983 to test titanium and aluminum plate-type heat exchangers and tube-in-shell heat exchangers constructed from materials other than titanium.

B.3 Seacoast Test Facility

The Seacoast Test Facility (STF) will be located at the Natural Energy Laboratory of Hawaii at Ke-ahole Point, Hawaii. The Seacoast Test Facility is a land-based OTEC plant from which biofouling and corrosion experiments will be conducted. These experiments will help develop long-term biofouling control measures for a variety of potential OTEC heat-exchanger materials and configurations.

The Seacoast Test Facility will be constructed and operated in two separate stages. The first stage, STF-1, is designed for the study of biofouling and corrosion control in experiments using only warm seawater drawn from the surface. Stage 2 (STF-2) is planned to be constructed during the operational period of STF-1. STF-2 is designed to expand the experimental program of STF-1 by investigating biofouling and corrosion control using both warm- and cold-seawater, which will be drawn from depths seaward of the STF-1 warm-water intake.

B.4 OTEC Pilot Plant

The DOE OTEC Program is presently at the stage of development where a pilot plant of intermediate electricity generating capacity is necessary to demonstrate the potential for commercial OTEC applications. The OTEC Pilot Plant will be used to develop design and construction methodology for commercial OTEC plants, acquaint user industries with the operating requirements and product potential of commercial OTEC plants, and determine the potential for cost reduction. The goal of the OTEC Pilot Plant Program is to demonstrate the technical and economic feasibility of OTEC electric power generation on a scale that is an order of magnitude greater than that previously tested and within a reasonable scale of a commercial plant.

The OTEC Pilot Plant Program consists of six phases:

- (I) Conceptual design
- (II) Preliminary design
- (III) Detailed design
- (IV) Construction, deployment, and acceptance test
- (V) Joint operational test and evaluation
- (VI) Transfer of ownership and contractor operation.

The Pilot Plant Program is presently entering the Conceptual Design phase. In an effort to stimulate the greatest possible interest in the Pilot Plant Program, the DOE elected to use the Program Opportunity Notice (PON) technique of solicitation for Phase I. The OTEC Pilot Plant PON was released by the DOE

in September 1980, with five to eight contracts for Pilot Plant conceptual design expected to be awarded in mid-1981. Phases II through VI will be exercised at the option of the DOE, and are expected to result in the deployment and operation of two OTEC Pilot Plants.

The closed-cycle OTEC Pilot Plant will have a minimum net capacity of 40 MWe, but the choice of platform configuration, plant design, and deployment site will be proposed by contract solicitors. Moored, bottom-resting tower, land-based, and grazing plantship designs are being considered for the OTEC Pilot Plant.

Appendix C

CANDIDATE OTEC AREA MAPS

This appendix presents a general overview of potential OTEC operational areas. These areas were selected by DOE for further investigation because they were deemed representative of regions in which commercial OTEC plants would be sited. The charts shown here illustrate the more salient features of potential siting regions, such as bottom topography, major landmasses, electrical grids, and specific locations of OTEC sampling and testing areas. An index to the charts in this section is provided in Figures 3-1a and 3-1b.

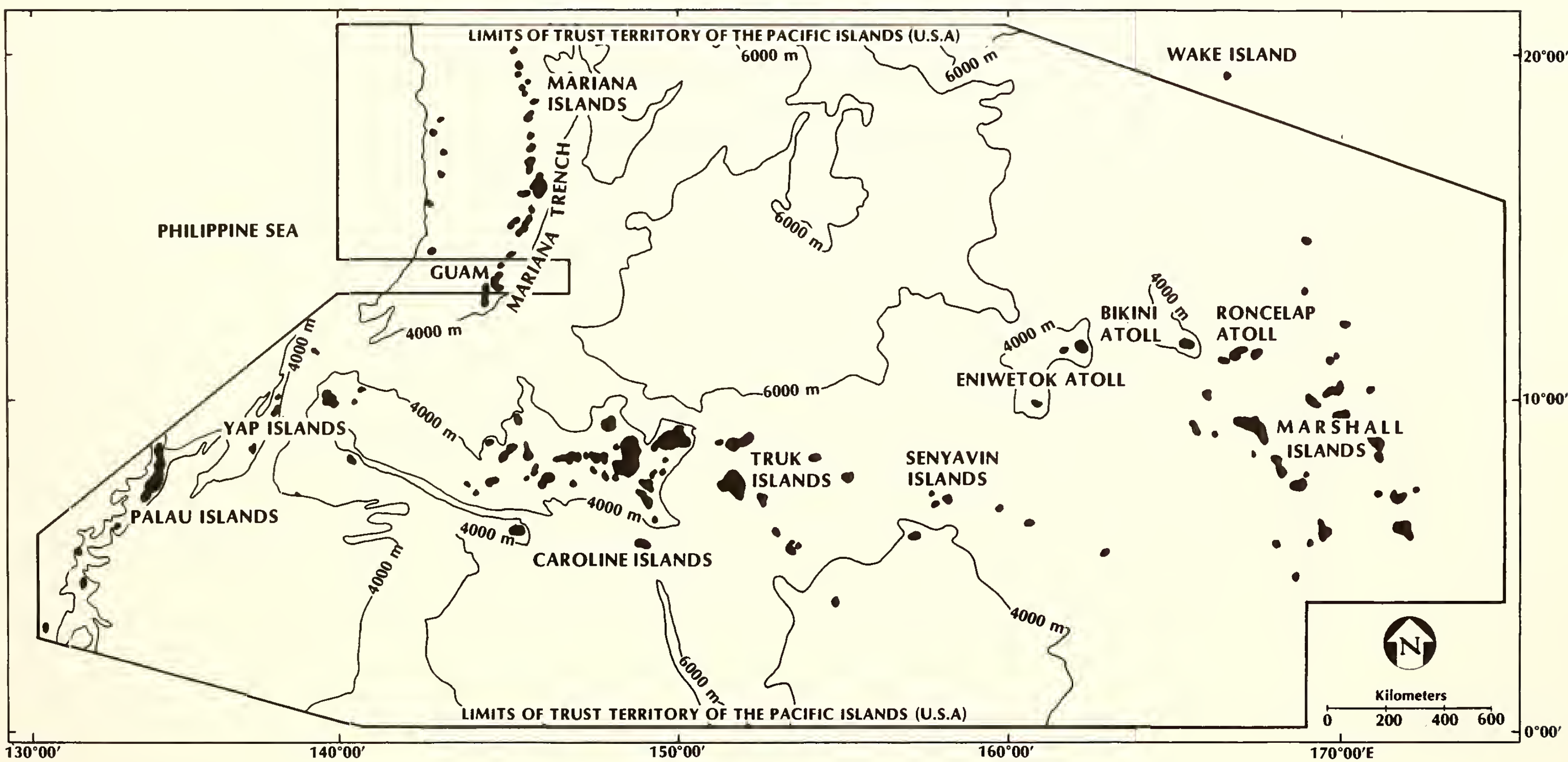

Figure C-1. Pacific Trust Territory
Source: U.S. Naval Oceanographic Office, 1969

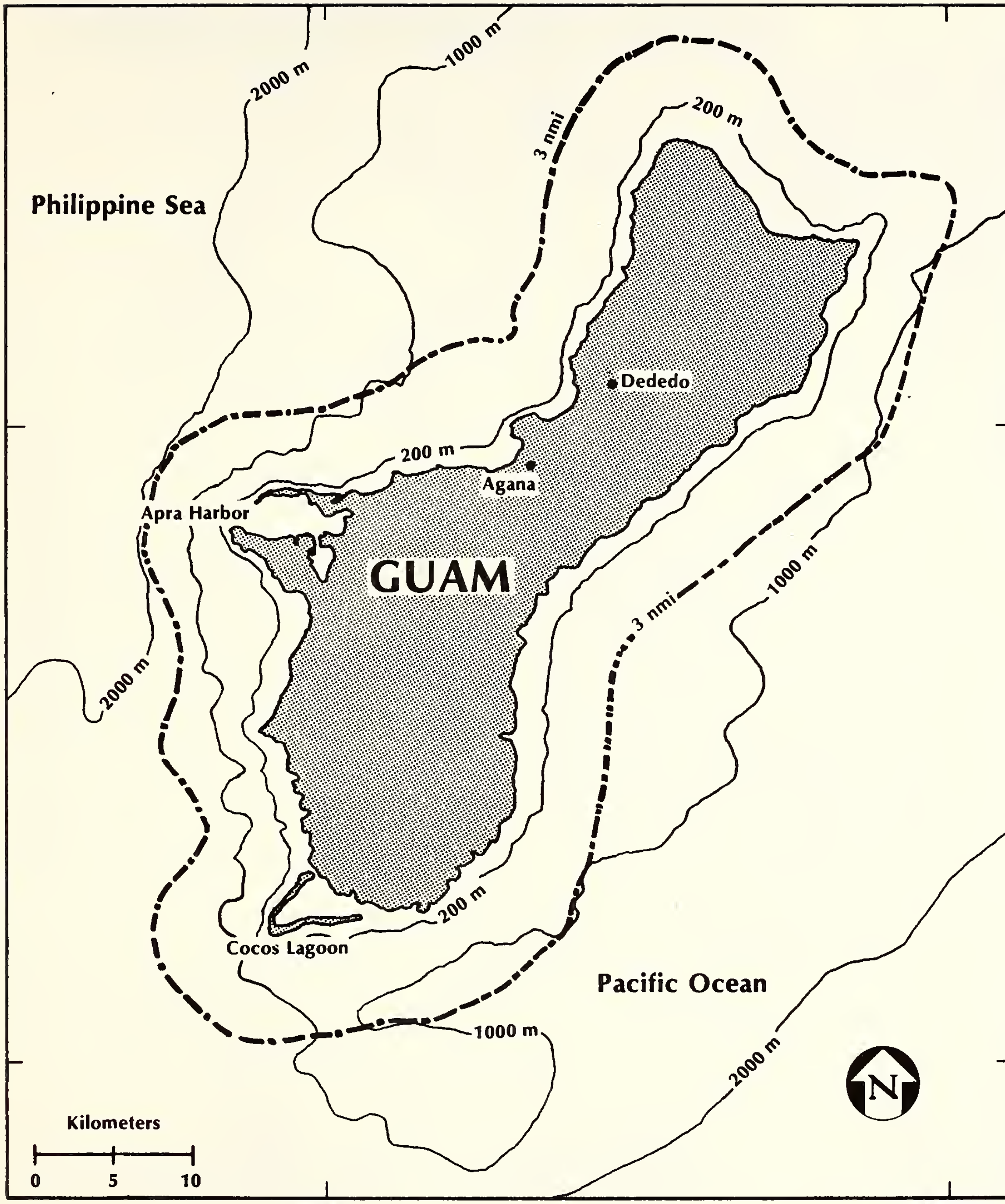

Figure C-2. Island of Guam
Source: U.S. Department of Commerce, 1971

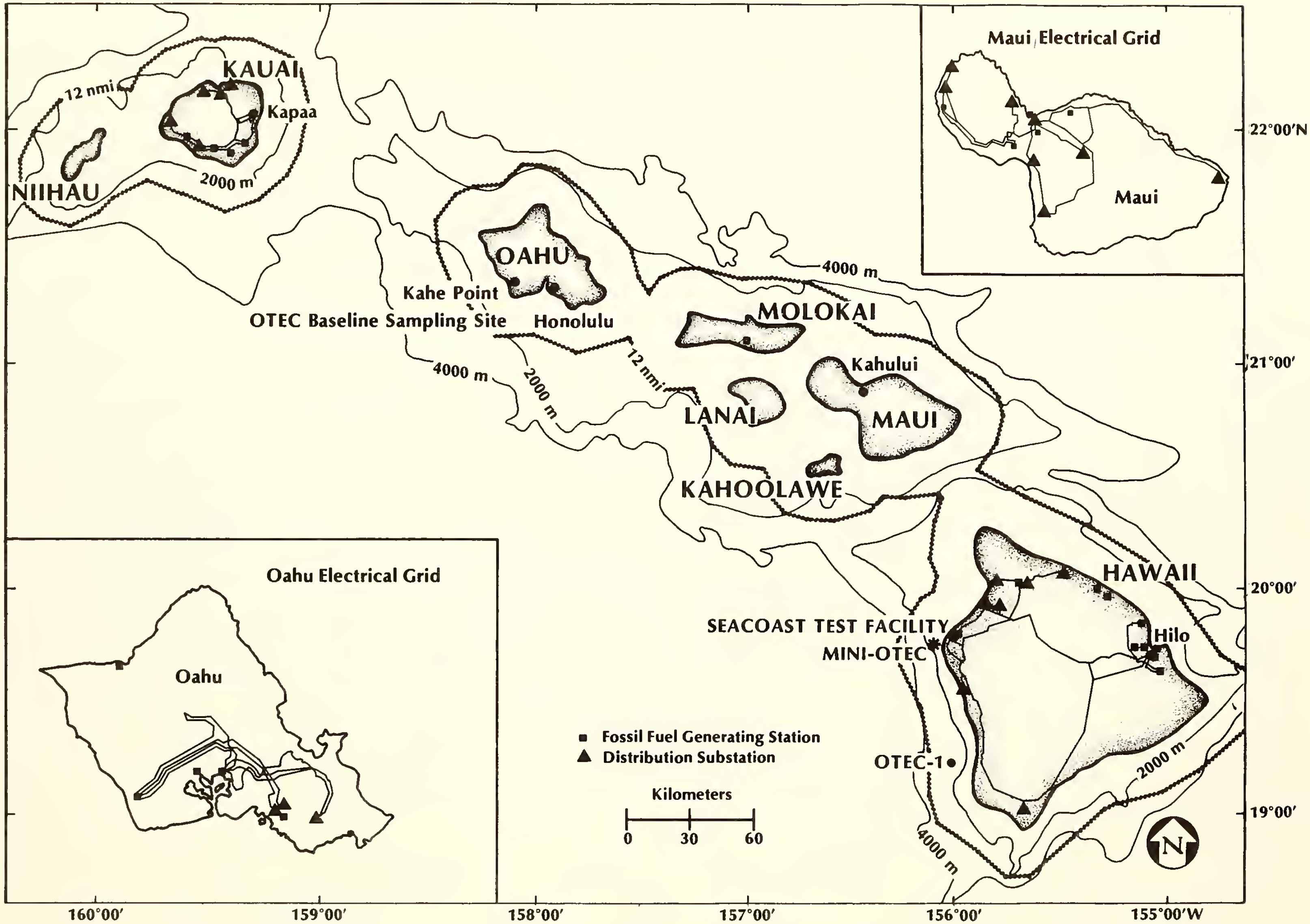

Figure C-3. Hawaiian Islands
Source: DOE, 1978d; DOC, 1978b

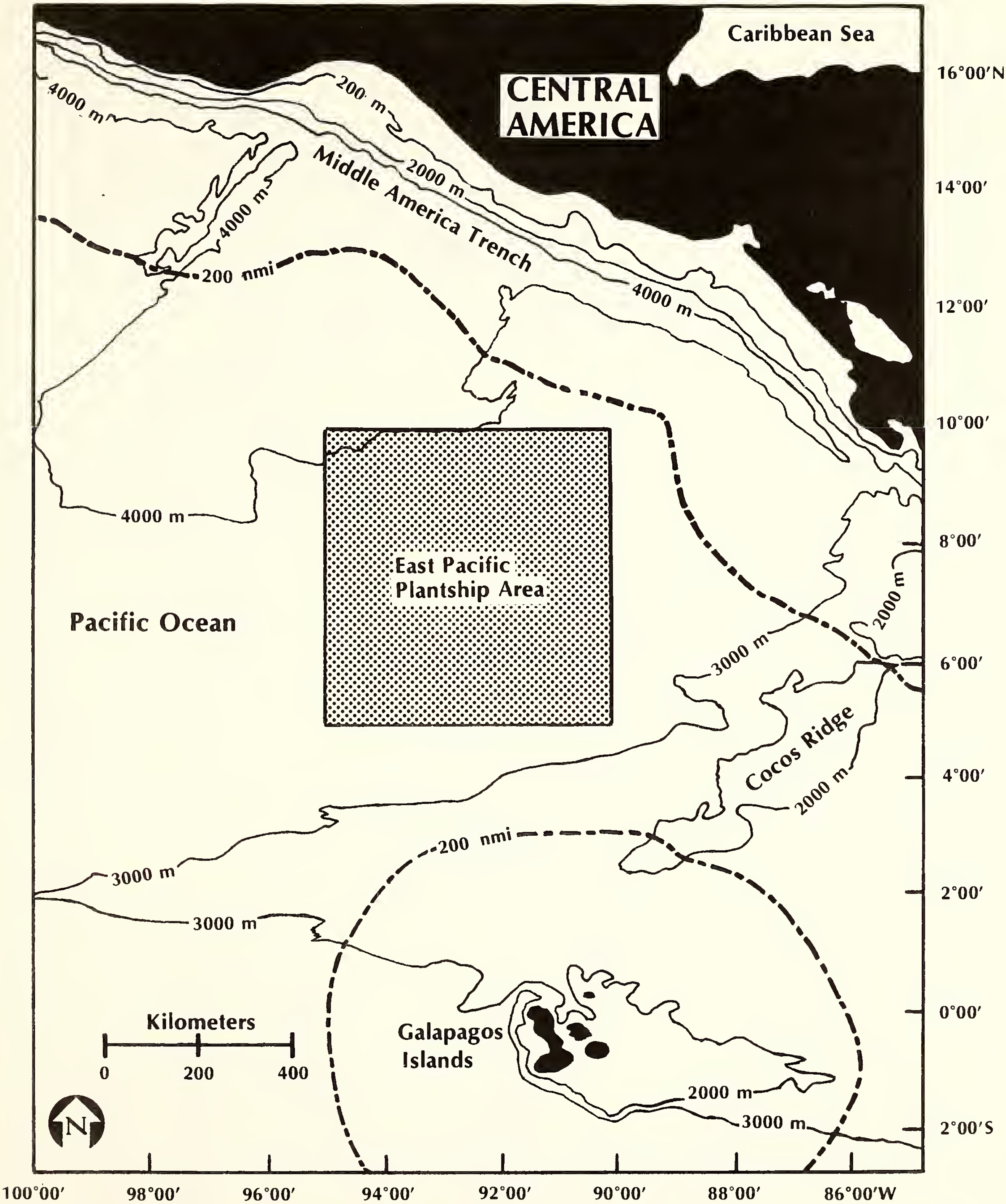

Figure C-4. East Pacific Plantship Region
Source: U.S. Naval Oceanographic Office, 1973

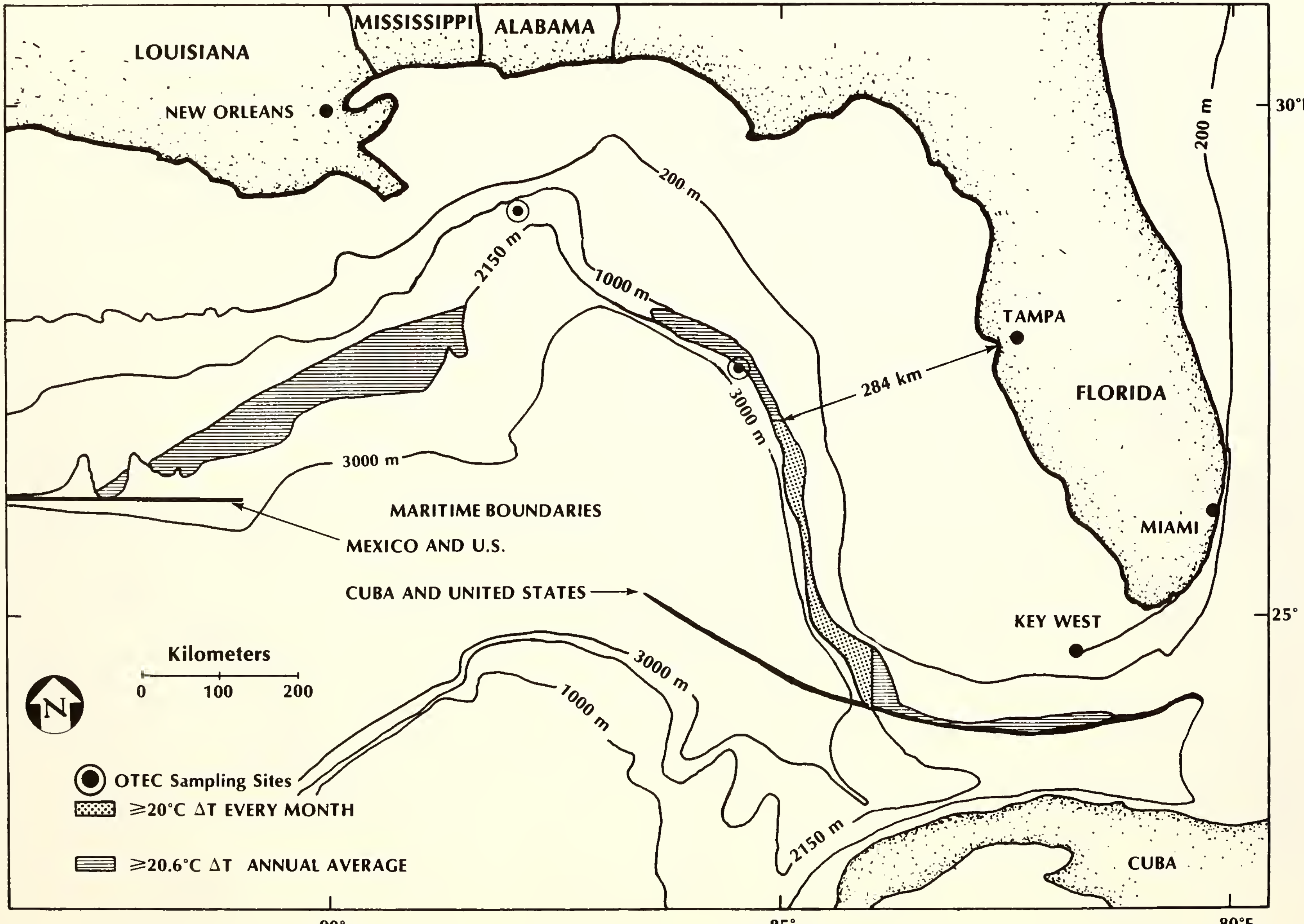

Figure C-5. Eastern Gulf of Mexico
Source: Molinari and Festa, 1978; U.S. Department of State, 1979

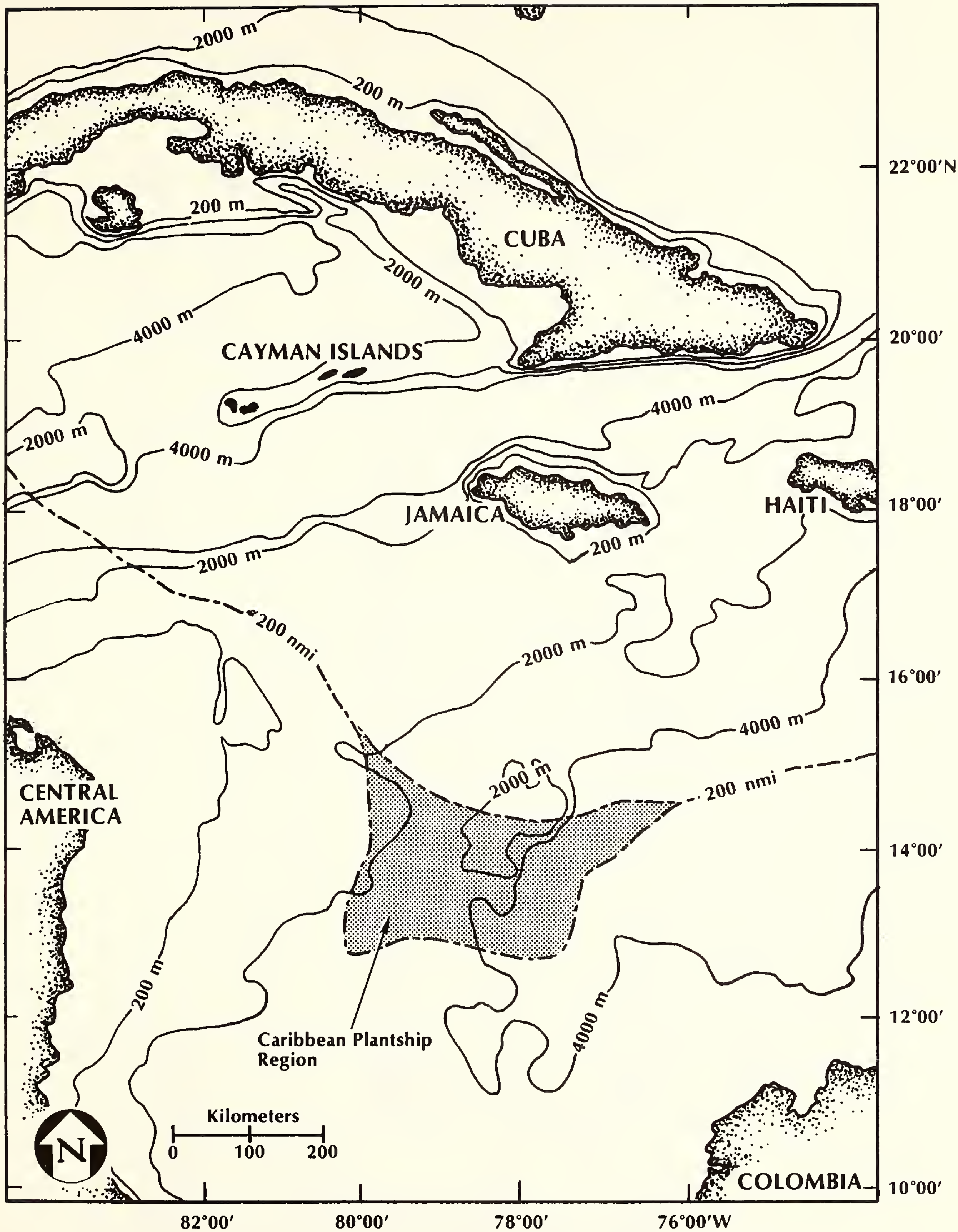

Figure C-6. Caribbean Plantship Region
Source: Defense Mapping Agency, 1979

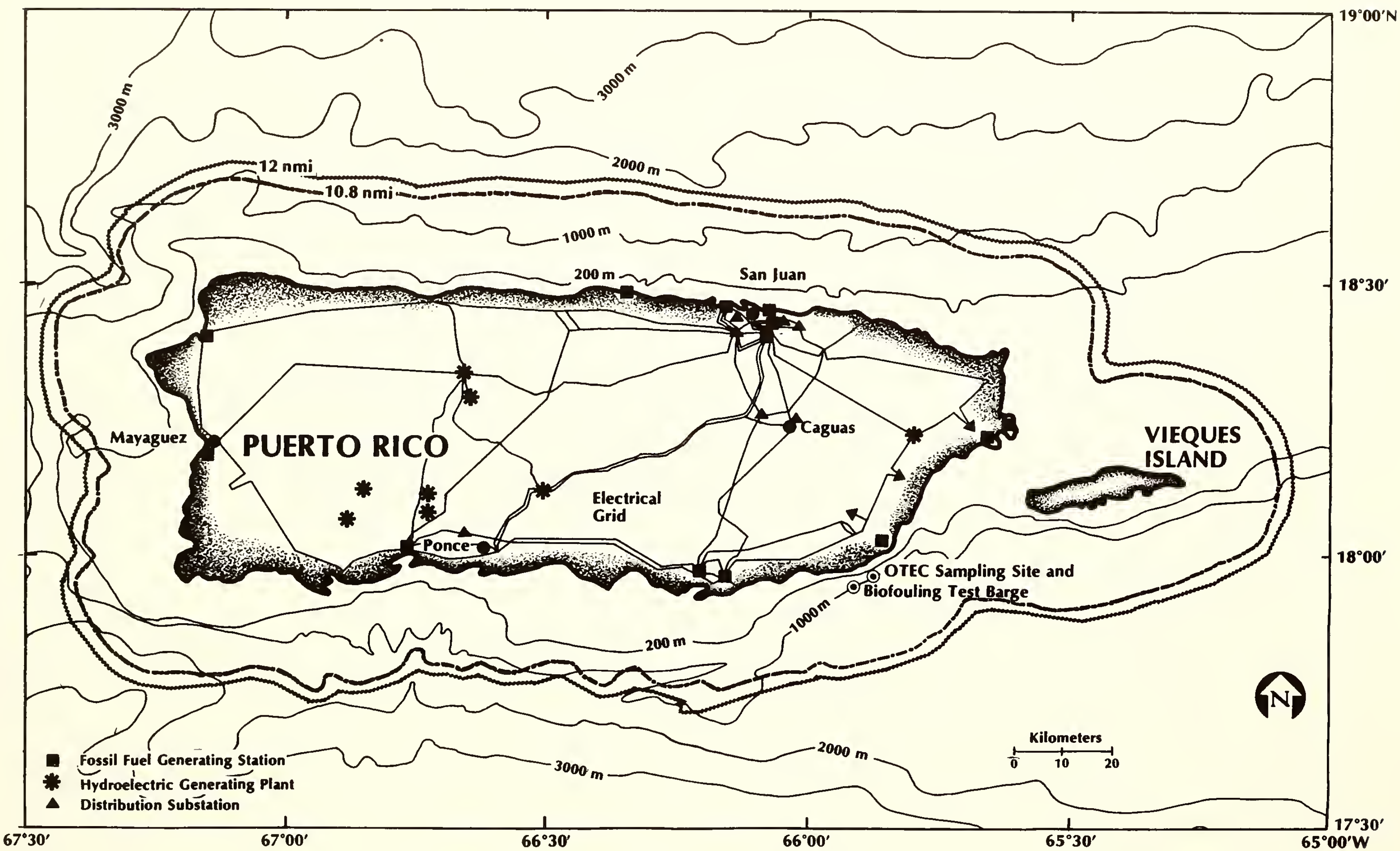

Figure C-7. Puerto Rico
Source: DOE, 1978d; U.S. Geological Survey, 1972

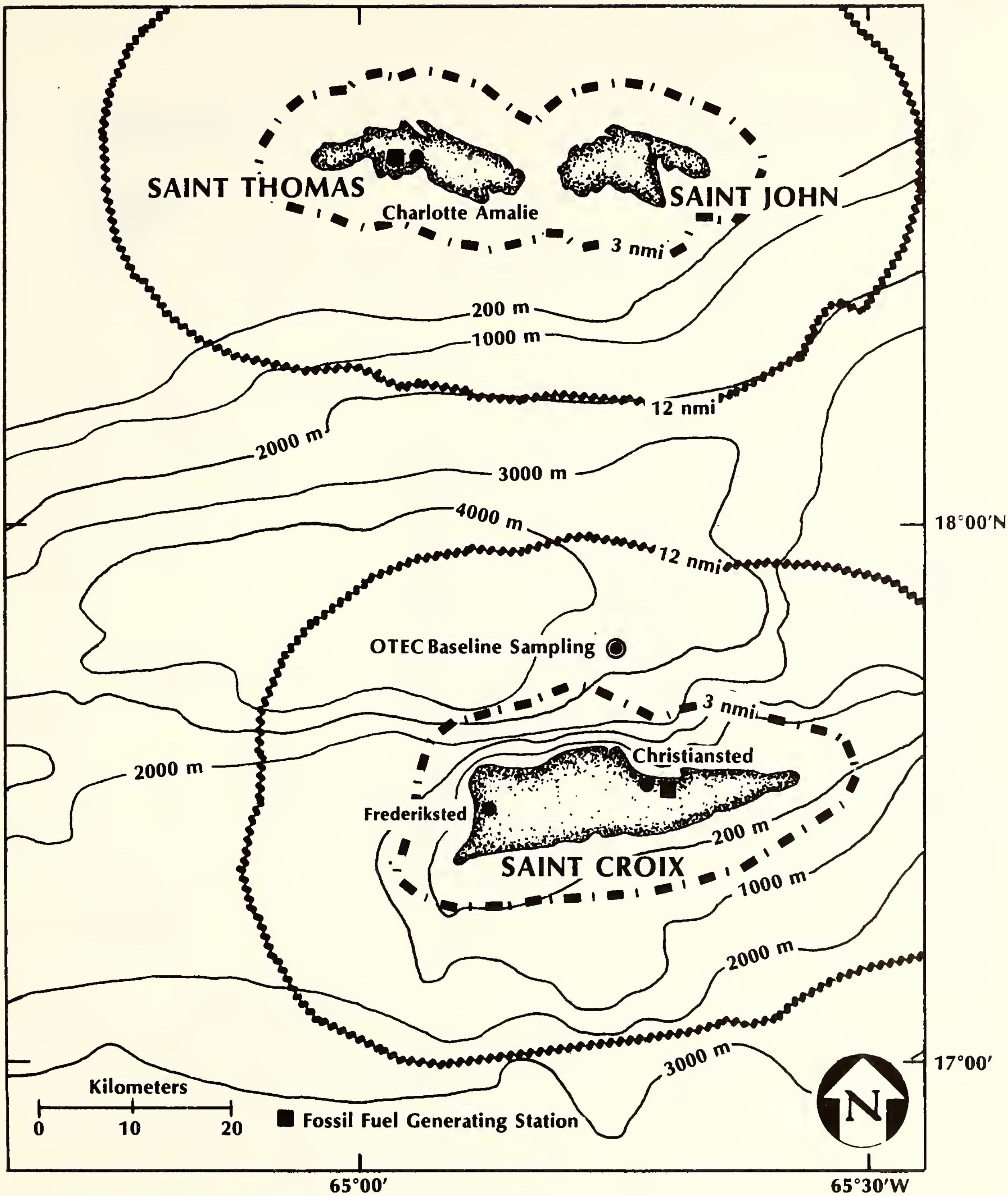

Figure C-8. U.S. Virgin Islands
Source: DOE, 1978d; U.S. Geological Survey, 1972

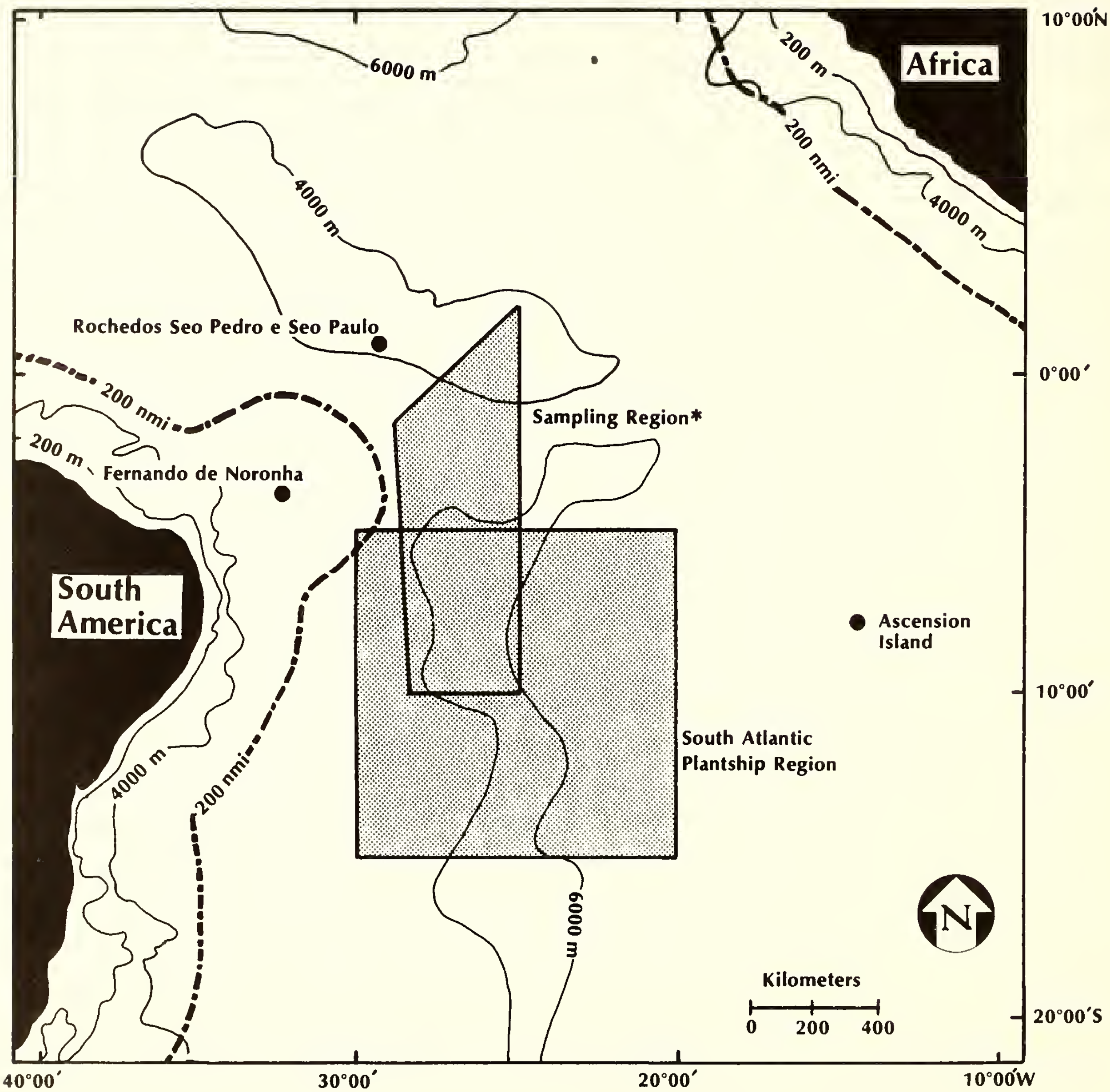

Figure C-9. South Atlantic Plantship Region
Source: U.S. Naval Hydrographic Office, 1951
*Region sampled by Lawrence Berkeley Laboratory (Wilde, 1979)

Appendix D

IMPACT AND RELATED CALCULATIONS

This section describes the mathematical models used to investigate the potential impacts of various aspects of OTEC operation. Values of physical, chemical, and biological parameters used in the calculations were derived from the environmental descriptions in Chapter 3. The flow rates used for the warm- and cold-water intakes of commercial OTEC plants are presented in Chapter 1.

D.1 PERCENT OF PROJECTED ELECTRICITY DEMAND TO BE SUPPLIED BY OTEC BY THE YEAR 2000

Gulf of Mexico and Puerto Rico. The percent of the projected electricity need for the year 2000 to be supplied by OTEC to the Gulf of Mexico and Puerto Rico was calculated by dividing the projected total OTEC power output by the projected energy demand for the year 2000. Table D-1 summarizes these calculations.

Hawaii, Virgin Islands, Guam, and Mariana Islands. The projected electricity consumption for the year 2000 was calculated by multiplying the current average annual per capita electricity usage for the Virgin Islands, the Hawaiian Islands, Guam, and the Northern Mariana Islands by the projected population for the year 2000. The percent of the projected electricity need for the year 2000 to be supplied by OTEC was calculated by dividing the projected total OTEC power output by the projected electricity demand for the year 2000. The results are summarized in Table D-2.

TABLE D-1

PERCENT OF PROJECTED ELECTRICITY NEED FOR YEAR 2000-
GULF OF MEXICO AND PUERTO RICO

Area	Electricity Consumption for the Year 2000 (10^{12} BTU)	Electricity Consumption for the Year 2000 (10^8 MWh)	Projected Electricity Supplied by OTEC by Year 2000 (10^8 MWh)	Percent of Total Projected by Year 2000
Gulf of Mexico (including Alabama, Florida, Louisiana, Mississippi, and Texas)	21,700	63	0.2	<1
Puerto Rico	588	2	0.09	5

D.2 CARBON DIOXIDE RELEASE FROM ALUMINUM PRODUCTION

The production of aluminum (Al) from alumina (Al_2O_3) results in the release of carbon dioxide (CO_2). The Alcoa process and the drained-cathode Hall process release different amounts of carbon dioxide. The calculations in this section involve only the carbon dioxide released by the actual reduction of alumina, and do not consider the additional carbon dioxide released through the generation of electricity to drive the process. A 400-MWe plantship will release 5.5×10^5 to 9.0×10^5 metric tons of carbon dioxide per year in the generation of electricity (Sands, 1980).

Alcoa Process. A 100-MWe plantship using the Alcoa process can produce about 7.8×10^4 metric tons of aluminum per year (Jones et al., 1980). Assuming a direct increase in aluminum output with increasing plantship generating capacity, a 400-MWe plantship will produce about 3.1×10^5 metric tons of aluminum per year.

TABLE D-2. PERCENT OF THE PROJECTED ENERGY NEED TO BE SUPPLIED BY OTEC BY THE YEAR 2000 TO THE VIRGIN ISLANDS, HAWAIIAN ISLANDS, GUAM, AND THE NORTHERN MARIANA ISLANDS

	Power Consumed (Year) (MWh)	Approximate Population (Year)	Average Annual Per Capita Electricity Usage (Year) (MWh/person)	Projected Population for Year 2000	Projected Electricity Demand for Year 2000 (MWh)	Electricity Supplied by OTEC for Year 2000 (MWh)	Percent Of Projected Electricity Need Supplied Supplied by OTEC for Year 2000
Virgin Islands							
St. Croix	177,000 (1979)[a]	48,000 (1979)[b]	4 (1979)	82,000[b]	300,000	300,000	100
St. Thomas, St. John	222,000 (1979)[a]	47,000 (1979)[b]	5 (1979)	67,000[b]	300,000	300,000	100
Hawaiian Islands [c]							
Oahu	4,900,000 (1977)	723,400 (1977)	7 (1977)	917,400	6,000,000	5,000,000	80
Hawaii	380,000 (1977)	78,100 (1977)	5 (1977)	123,300	600,000	300,000	50
Kauai	170,000 (1977)	33,800 (1977)	5 (1977)	60,400	300,000	300,000	100
Maui, Lanai, Molokai	380,000 (1977)	59,400 (1977)	6 (1977)	124,700	800,000	700,000	90
Guam	1,000,000 (1980)[d]	125,000 (1980)[e]	8 (1980)	200,000[e]	1,600,000	1,600,000	100
Northern Mariana Islands	No information	16,200 (1978)[f]	6[g]	34,000[f]	204,000	175,200	90

Sources

(a) Martin, 1980.

(b) U.S. Department of Commerce, 1979b.

(c) State of Hawaii, 1978.

(d) Smith, 1981.

(e) U.S. Dept. of Commerce, 1979a.

(f) U.S. Dept of Commerce, No Date.

(g) No information available for Guam. Value is mean of other island areas.

The Alcoa process releases carbon dioxide through the reduction of alumina to aluminum chloride ($AlCl_3$):

$$\text{(A)} \quad 2\ Al_2O_3 + 3C + 6Cl_2 \rightarrow 4\ AlCl_3 + 3\ CO_2$$

Aluminum chloride is further reduced to aluminum

$$\text{(B)} \quad 2AlCl_3 \rightarrow 2Al + 3\ Cl_2.$$

3.1×10^5 metric tons of aluminum is equal to 1.1 of 10^{10} moles of aluminum:

$$(3.1 \times 10^{11}\ \text{g Al}) \ \frac{1\ \text{mole Al}}{27\ \text{g Al}} = 1.1 \times 10^{10}\ \text{moles Al}.$$

One mole of alumina is required to produce two moles of aluminum (Equations A and B); 1.1×10^{10} moles of aluminum consequently requires 5.5×10^9 moles of alumina. The reduction of two moles of alumina produces three moles of carbon dioxide (Equation A); 5.5×10^9 moles of alumina will consequently produce 8.2×10^9 moles, or 3.6×10^5 metric tons, of carbon dioxide.

$$(8.2 \times 10^9\ \text{moles}\ CO_2) \ \frac{44\ \text{g}\ CO_2}{1\ \text{mole}\ CO_2} = 3.6 \times 10^{11}\text{g}\ CO_2$$

$$= 3.6 \times 10^5\ \text{metric tons}\ CO_2.$$

The annual production of 3.1×10^5 metric tons of aluminum using the Alcoa process will release 3.6×10^5 metric tons of carbon dioxide.

Drained-Cathode Hall Process. A 100-MWe plantship could produce about 6.4×10^4 metric tons of aluminum per year through the drained-cathode Hall process (Jones et al., 1980); correspondingly, a 400-MWe plantship could

produce 2.6×10^5 metric tons of aluminum per year. A simplified description of the reduction of alumina (Equation C) shows that this process produces carbon dioxide in the same proportion to aluminum as the Alcoa process:

$$\text{(C)} \qquad 2Al_2O_3 + 3C \rightarrow 4Al + 3CO_2.$$

2.6×10^5 metric tons of aluminum is equal to 9.6×10^9 moles of aluminum; this requires 4.8×10^9 moles of alumina, producing 7.2×10^9 moles of carbon dioxide, or 3.2×10^5 metric tons of carbon dioxide.

An annual production of 2.6×10^5 tons of aluminum through the drained cathode Hall process could result in the release of 3.2×10^5 metric tons of carbon dioxide.

D.3 PROJECTED CARBON DIOXIDE RELEASE THROUGH OTEC OPERATION BY THE YEAR 2000

The following calculations present an order of magnitude estimate of the amount of carbon dioxide that could be released from OTEC deployment according to the scenario for the year 2000 (Table 1-3). Carbon dioxide release was calculated for open- and closed-cycle generating plants, and ammonia- and aluminum-producing plantships.

Closed-cycle Baseload Generating Plants. The total baseload generating capacity is predicted to be 3580 MWe by the year 2000. At an estimated release rate of 5 metric tons of carbon dioxide per MWe per day (Sands, 1980), 6.5×10^6 metric tons of carbon dioxide will be released per year.

Open-cycle Baseload Generating Plants. Open-cycle plants are projected to supply 830 MWe by the year 2000. At a carbon dioxide release rate of about 57 metric tons per MWe per day (Section D.4), the projected open-cycle deployment will release 1.7×10^7 metric tons of carbon dioxide per year by the year 2000.

Aluminum- and Ammonia-producing Plantships. Aluminum- and ammonia- producing plantships could produce 2200 MWe of electricity through a closed-cycle system by the year 2000. This will release about 4×10^6 metric tons of carbon dioxide per year. In addition, projected aluminum production will release about 3.4×10^5 metric tons of carbon dioxide per year (Section D.2). The estimated plantship deployment by the year 2000 could release a total of 4.3×10^6 metric tons of carbon dioxide per year.

Total Carbon Dioxide Output by the Year 2000.

Closed-cycle baseload electricity generation	6.5×10^6 metric tons CO_2
Open-cycle baseload electricity generation	17×10^6 metric tons CO_2
Plantship operation and aluminum production	4.3×10^6 metric tons CO_2
Total	27.8×10^6 metric tons CO_2

D.4 OPEN-CYCLE CARBON DIOXIDE DISCHARGE

Open-cycle plant operation requires the removal of non-condensible gases from the working fluid system (Watt et al., 1978). This will release large quantities of carbon dioxide.

Flow rates for a 40 MWe open-cycle OTEC plant are estimated to be 209 $m^3\ sec^{-1}$ and 159 $m^3\ sec^{-1}$ for the warm and cold water systems, respectively (Watt et al., 1977). At an average seawater density of 1.025 $g\ l^{-1}$ (Gross, 1977), the mass flow rates are 2.14×10^5 kg sec^{-1} for warm water, and 1.63×10^5 kg sec^{-1} for cold water.

Carbon dioxide concentrations at the surface and at 1100 m were taken from Takahashi et al., (1970). These values were measured in the eastern North Pacific Ocean and will be used to represent typical ocean values.

Total carbon dioxide available (Takahashi et al., 1970):

Warm water (surface)

$$1.947 \times 10^{-3} \text{ moles } CO_2 \text{ kg}^{-1} \text{ seawater}$$
$$= 8.567 \times 10^{-5} \text{ kg } CO_2 \text{ kg}^{-1} \text{ seawater}$$

Cold water (1100 m)

$$2.328 \times 10^{-3} \text{ moles } CO_2 \text{ kg}^{-1} \text{ seawater}$$
$$= 1.024 \times 10^{-4} \text{ kg } CO_2 \text{ kg}^{-1} \text{ seawater}$$

Assuming that 75% of the equilibrium condition gas is liberated by the plant (Watt et al., 1978), the amount of CO_2 released is equal to:

$$(0.75)(\text{Total } CO_2 \text{ available})(\text{Mass flow rate}) = \text{Total } CO_2 \text{ released}$$

$$(0.75)(8.567 \times 10^{-5} \text{ kg } CO_2 \text{ kg}^{-1}\text{seawater})(2.14 \times 10^{5} \text{ kg seawater sec}^{-1})$$

$$+(0.75)(1.024 \times 10^{-4} \text{ kg } CO_2 \text{ kg}^{-1}\text{seawater})(1.63 \times 10^{5} \text{ kg seawater sec}^{-1})$$

$$= 26.3 \text{ kg } CO_2 \text{ sec}^{-1}$$

A 40 MWe open-cycle plant could release 26.3 kg of carbon dioxide per second, or 2270 metric tons of carbon dioxide per day.

D.5 LARVAL ENTRAINMENT

Natural variations in the geographic distribution of organisms makes the siting and spacing of OTEC plants a determining influence in the nature and magnitude of larval entrainment. The potential impacts of different siting and spacing alternatives are illustrated in the following model. These calculations consider the impact of larval entrainment on three species of commercially-exploited fish, representing different life histories, found around the island of Oahu, Hawaii. The primary purpose of this model is to

illustrate the different natures and magnitudes of entrainment impacts resulting from various OTEC siting and spacing configurations. The results present an order of magnitude estimate of the impacts to commercial fisheries of OTEC deployment around an island community.

Larval entrainment for each species is estimated for three 400-MWe OTEC plants (1) clustered off Kahe Point, (2) clustered off Waimea Bay, and (3) spaced evenly around Oahu. Because impacts may vary with different types of fish, three species representing different life histories were selected: a carangid, *Seriola* spp. (kahala, amberjack), a pelagic/neritic species with pelagic eggs; a pomacentrid, *Abudefduf abdominalis* (maomao, damselfish), an inshore reef species with demersal eggs; and a scombrid, *Thunnus albacores* (ahi, yellow-fin tuna), an offshore species with pelagic eggs.

The model follows the following four steps:

(a) The distribution and density of larvae of three commercially-important fish were estimated.

Larval distribution around Oahu was obtained from the literature; larval density was averaged from sampling stations located nearest the plant locations used (Figure D-1).

(b) Larval entrainment for each species was estimated for the three different deployment scenarios.

Larval entrainment was estimated by multiplying larval density by the plant's warm-water flow rate.

(Larval density) (Flow rate) = Entrainment estimate.

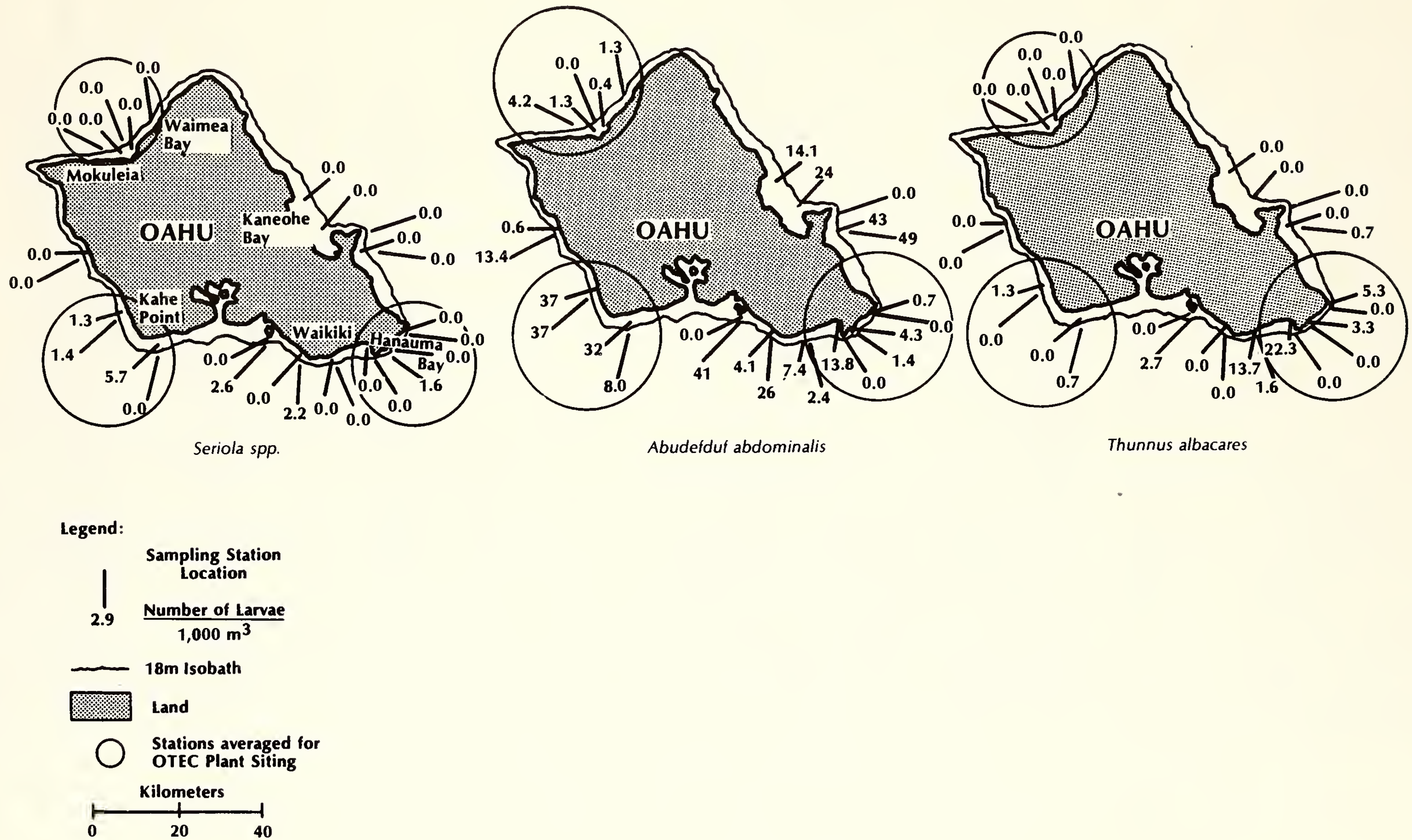

Figure D-1. Summer Densities of Larvae of Three Commercially-Important Species of Fish Around Oahu, Hawaii (Number of Larvae per 1,000 m^3)
Source: Miller et al., 1979

Entrainment values were assumed to be additive for multiple plant deployment. For a three-plant cluster off Kahe Point, the entraiment of *Seriola* spp. was calculated as:

$$3(0.0021\ m^{-3})\ (173 \times 10^{6}\ m^{3}\ day^{-1})\ (365\ days\ year^{-1}) = 4.0 \times 10^{8}\ year^{-1}$$

(c) Entrainment estimates were converted to equivalent adult losses.

The impact of larval entrainment on adult populations was assessed using a model developed by Horst (1975). This model estimates the equivalent loss of adults from larvae killed by entrainment and takes into account the natural survivorship of larvae to adults. Although natural survivorship changes with age and size of larvae (Goodyear, 1978), Horst's model can be used when data limitations preclude the use of more sophisticated models; it presents an order-of-magnitude estimate of the effect fish larvae entrainment will have on fish populations of an area. The model is:

$$N_a = S_1 N_e$$

Where N_a = number of adults that would have resulted from the entrain larvae

S_1 = survivorship from larvae to adulthood

N_e = number of larvae killed by entrainment

Assuming 100% mortality of entrained larvae, N_e equals the number of larvae entrained. The percent survival (S_1) of the three species chosen was not available; values reported in the literature were compared and 1.0×10^{-5} was selected to provide an order of magnitude estimate (Lawler, Matusky, and Skelley Engineers, 1980; Marcy, 1973; Houde, 1977).

For a three-plant cluster off Kahe Point (*Seriola* spp.):

$$N_e \times S_1 = N_a$$

$$(4.0 \times 10^8)(1.0 \times 10^{-5}) = 4{,}000 \text{ adults}$$

(d) Adult losses were compared with commercial catch statistics from the Hawaiian Islands.

The equivalent adult losses were adjusted by the average weight of a commercial catch-sized adult to yield equivalent adult weight. The equivalent weight was then compared with commercial catch statistics of Hawaii (Table D-3).

The results (1) suggest that a cluster of three OTEC plants near Kahe Point will generally have a greater larval entrainment impact than three plants spaced evenly around the island, (2) indicate that OTEC deployment in the nearshore zone will impact nearshore fisheries, such as damsel fish, to a much greater degree than offshore fisheries, such as tuna, and (3) present an order-of-magnitude estimate of the impact of OTEC operation on Hawaiian fisheries (Table D-3).

The accuracy of the results is limited by the following considerations:

- Larval densities are for summer only, yearly averages are not available. Summer densities are generally higher than winter densities (Miller et al., 1979), consequently the entrainment estimates are probably higher than actual values.

- Larval densities were from surface samples only; the model did not consider the vertical distribution of larvae and the depth of warm-water intake.

- An additive increase in entrainment from multiple plant deployments may be a simplistic assumption.

TABLE D-3. ESTIMATED EQUIVALENT COMMERCIAL VALUE OF FISH LOST BY ENTRAINMENT OF LARVAE AT OAHU, HAWAII FOR DIFFERENT LOCATIONS AND DEPLOYMENT PATTERNS

Species	Size of Operation	Yearly Larvae Entrainment Estimate	Equivalent Number* of Adults Lost	Average+ Adult Weight (kg)	Equivalent Weight (kg)	Cost+ Per kg ($)	Equivalent Commercial Value ($)	1978 Catch Statistics for Hawaii		Proportion of Commercial Catch Lost	
								Weight (kg)	Value ($)	Weight	Value
Seriola spp. (amberjack)	Three 400-MWe plants off Kahe Point	4.0×10^8	4,000	7.9	31,700	2.11	66,900	45,000	95,000	0.7	0.7
	Three 400-MWe plants off Waimea Bay	0	0	7.9	0	2.11	0	45,000	95,000	0.0	0.0
	Three 400 MWe plants spaced around Oahu	1.5×10^8	1,500	7.9	11,800	2.11	24,900	45,000	95,000	0.3	0.3
Abudefduf abdominalis (damsel fish)	Three 400-MWe cluster off Kahe Point	5.5×10^9	54,700	0.2	10,900	2.27	24,700	1,630	3,700	6.7	6.7
	Three 400-MWe cluster off Waimea	2.7×10^8	2,700	0.2	540	2.27	1,200	1,630	3,700	0.3	0.3
	Three 400-MWe plants spaced around Oahu	2.1×10^9	21,200	0.2	4,200	2.27	9,500	1,630	3,700	2.6	2.6
Thunnus albacares (yellowfin tuna)	Three 400-MWe plants off Kahe Point	9.5×10^7	950	45.4	43,100	2.09	90,100	960,000	2,000,000	0.1	0.1
	Three 400-MWe plants off Waimea	0	0	45.4	0	2.09	0	960,000	2,000,000	0.0	0.0
	Three 400-MWe plants spaced around Oahu	3.5×10^8	3,500	45.4	157,400	2.09	329,000	960,000	2,000,000	0.2	0.2

* Percent survival from eggs to adult estimated at 1.0×10^{-5} (Lawler Matusky and Skelly Engineers, 1980; Marcy, 1973).
\+ Sumida, 1980. (For *Thunnus albacares* a range of weights was reported and 45 kg taken as average).

Despite these limitations, the results can be used to show that the impact of larval entrainment on different species of marine organisms is strongly dependent on plant siting and spacing.

D.6 IMPINGEMENT

The nekton impingement estimate was obtained by extrapolating from data taken at conventional land-based generating plants. The following sites were compared: (1) the Kahe Generating Station, located in a tropical open coast area in Oahu, Hawaii, (2) a generating station located on Galveston Bay in the Gulf of Mexico.

The lower impingement values from the Kahe Generating Station are more likely to be representative of impingement from a land-based OTEC plant located on a tropical island, whereas the other station is used to estimate impingement rates in an area of higher productivity. Only impingement at the warm-water intake was considered, impingement at the cold water intake was not estimated because there is no data available on impingement of deep-water organisms.

Kahe Generating Station. Unit 5 of the Kahe Generating Station, Oahu, withdraws about 9.5 m^3 sec^{-1} of nearshore water at velocities similar to those of an OTEC plant, resulting in the impingement of an average of 250 g (wet weight) of fish daily (McCain, 1977). A 400-MWe OTEC plant will withdraw about 210 times more water through the warm-water intake than Unit 5. Assuming that impingement is directly proportional to the volume of water withdrawn, a 400-MWe OTEC plant will impinge about 50 kg of organisms per day.

Gulf Mexico. The P.H. Robinson Generating Station in Galveston Bay, Gulf of Mexico, withdraws about 50 m^3 sec^{-1} of nearshore water, resulting in the daily impingement of 110 kg (wet weight) of nektonic organisms (Landry, 1971

after Coles, 1979). A 400-MWe OTEC plant will withdraw about 40 times more water through the warm-water intake. Assuming a direct increase in impingement with volume of water withdrawn, this could result in the impingement of about 4400 kg of organisms per day.

D.7 NUTRIENT REDISTRIBUTION

The discharge of nutrient-rich waters into the photic zone will increase the productivity of an area and may alter the existing food chain. To demonstrate the differences between food chains in oceanic, coastal, and upwelling areas, the phytoplankton biomass (mg C day^{-1}) which could be produced as a result of nutrients released by a 400-MWe OTEC plant was calculated. Assuming a 400-MWe plant will discharge cold water with a nitrogen concentration of 30 μg-atom liter^{-1} (30 mg-atom N m^{-3}; Table 3-2) at a flow rate of 2,000 m^{3} sec^{-1}, (Table 1-1) then 5.18 x 10^{9} mg-atom N day^{-1} will be redistributed:

$$30 \text{ mg-atom N m}^{-3} \times 2000 \text{ m}^{3} \text{ sec}^{-1} \times 60 \text{ sec min}^{-1} \times 60 \text{ min hr}^{-1}$$
$$\times\ 24\text{-hr day}^{-1} = 5.18 \times 10^{9} \text{ mg-atom N day}^{-1}$$

The phytoplankton uptake ratio for nitrogen to carbon is 16:106 (Redfield et al., 1963). Following this ratio, the amount of nitrogen released in a day would result in the production of 4.1 x 10^{5} kg carbon of phytoplankton biomass.

$$5.18 \times 10^{9} \text{mg-atom N day}^{-1} \times \frac{106 \text{ mg-atom C}}{16 \text{ mg-atom N}} \times \frac{12 \text{ mg C}}{1 \text{ mg-atom C}} =$$
$$4.1 \times 10^{11} \text{ mg C day}^{-1} = 4.1 \times 10^{5} \text{ kg C day}^{-1}$$

The efficiency of energy transfer between trophic levels and the number of trophic levels characteristic of the food chain which were used to calculate the effects of introducing 4.1 x 10^{5} kg C day^{-1} into the environment are shown in Table D-4.

TABLE D-4. IMPACTS OF BIOMASS INCREASE TO OCEANIC, COASTAL, AND UPWELLING FOOD CHAINS.

Source: Ryther, after Schaeffer (1969)

Oceanic (10% Efficiency)

Nannoplankton → (small flagellates)	Microzooplankton → (herbivorous zooplankton)	Macrozooplankton → (carnivorous zooplankton)	Megazooplankton → (chaetognaths, euphausiids)
410,000 kg C day^{-1}	41,000 kg C day^{-1}	4,100 kg C day^{-1}	410 kg C day^{-1}
Planktivores → (lanternfish, saury)	Carnivores (squid, tuna)		
41 kg C day^{-1}	4.1 kg C day^{-1}		

Coastal (15% Efficiency)

Phytoplankton → (diatoms, dinoflagellates)	Macrozooplankton → (herbivorous zooplankton)	Planktivores → (clupeids)	Carnivores (tuna)
410,000 kg C day^{-1}	61,500 kg C day^{-1}	9,230 kg C day^{-1}	1,380 kg C day^{-1}

Upwelling (20% Efficiency)

	Planktivores (clupeids)	
Macrophytoplankton (large, chain-forming diatoms and dinoflagellates) →		→ Carnivores (tuna)
	Megazooplankton (euphausiids)	
410,000 kg C day^{-1}	82,000 kg C day^{-1}	16,400 kg C day^{-1}

D.8 LOW FREQUENCY SOUND EMISSION

The impact of anthropogenic sound on marine organisms can be demonstrated by referring to calculations by Payne and Webb (1971) on the interference of oceanic traffic noise with low frequency sounds produced by fin whales *(Balaenoptera physalus)*. Noise from oceanic traffic has a frequency range from 10 Hz to 1000 Hz, with a peak intensity at about 50 Hz (Wenz, 1964); fin whales produce loud signals at around 20 Hz (Schevill et al., 1964). Payne and Webb (1971) assume that these sounds represent a method of communication among fin whales. Using a 0 dB signal-to-noise ratio (S/N) as the threshold detection level, Payne and Webb (1971) calculated that noise from present day shipping activity can reduce the effective range of a 20 Hz signal by a minimum of 70% from the range during pre propeller-ship conditions (Table D-5).

D.9 SALINITY INCREASE IN OPEN-CYCLE SEAWATER WORKING FLUID.

The operation of an open-cycle OTEC plant involves flash evaporation of the seawater working fluid. About one percent of the seawater passing through the plant is evaporated (Watt et al., 1977). Assuming the seawater entering the plant has a salinity of 35 ppt, this will increase the salinity of the remaining fluid by 0.35 ppt.

D.10 AMMONIA RELEASE

Approximately 6.4×10^6 kg of ammonia (NH_3) will be stored on a 400-MWe OTEC plant. During a large spill, 60% of the ammonia (3.8×10^6 kg) will dissolve in the mixed layer, and the remaining 40 percent will be released to the atmosphere. An ammonia concentration of 1 mg liter^{-1} (10^{-3} kg m^{-3}), was found to cause a 50 percent mortality in oceanic shrimp and fish (Venkataramiah, 1979). The dissolved ammonia will produce a lethal concentration of 1 mg liter^{-1} in 3.8×10^9 m^3 of water.

TABLE D-5. CALCULATED MAXIMUM RANGES AT WHICH FIN WHALE 20 HZ SOUNDS REACH 0 dB S/N* UNDER DIFFERENT BACKGROUND NOISE CONDITIONS.
Source: Modified from Payne and Webb, 1971

Background Noise Level	Minimum range in deep ocean (Spherical spreading)		Maximum range in deep ocean (SOFAR** signaling conditions)	
	Range (km)	Area of circle with radius equal of range (km^2)+	Range (km)	Area of circle with radius equal to range (km^2)+
Present day (average conditions)	85	2.3×10^4	970	3.0×10^6
Pre propeller-ship++ ocean (average conditions)	260	2.1×10^5	6,500	1.3×10^8
Pre propeller-ship++ ocean (quiet conditions)	835	2.2×10^6	2.1×10^4	1.4×10^9

*0 dB S/N refers to the decibel level (dB) of signal to noise ratio. 0 dB S/N indicates one order of magnitude difference in intensities between signal and noise.

**SOFAR refers to deep sound channel.

+For comparison, the Pacific Ocean basin is about 2.2×10^8 km^2 and the Atlantic 1.2×10^8 km^2.

++Pre propeller-ship ocean refers to derived, ambient, ocean noise conditions prior to the advent of propeller ships.

$$\frac{\text{total } NH_3 \text{ in seawater}}{\text{lethal concentration}} = \text{volume of water with lethal concentration}$$

$$\frac{3.8 \times 10^6 \text{ kg } NH_3}{10^{-3} \text{ kg m}^{-3}} = 3.8 \times 10^9 \text{ m}^3$$

Assuming that the mixed layer is 60 m deep, this represents a lethal ammonia concentration over an area of 63 km^2.

A 400-MWe ammonia producing plantship will hold 6.4×10^6 kg of ammonia for working fluid. The ammonia product will be stored for a maximum of 30 days before being removed by ship. About 3.64×10^7 kg of ammonia can be produced in a 30 day period. Consequently, the total amount of ammonia that could be released in a catastrophic spill is 4.28×10^7 kg. Using the same calculations as above, this could result in a lethal concentration of ammonia through 428 km^2 of the mixed layer.

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